MOBILE COMMUNICATIONS WITHIN THE DEEPWATER LIFELINES

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This thesis researched the availability and applicability of using commercial off-the-shelf (COTS) cellular software and smartphone hardware platforms to address future individual communication requirements for the US Navy at sea. The paper presents evidence in favor of incorporation of COTS technology aboard ships to address tactical communications. Individual communication needs facilitated by devices include text, chat, voice, position location information, imagery and map viewing, streaming video, web browsing and e-mail. While all of these identified communication capabilities are currently available in military command and control systems, they presently reside primarily at hardwired workstations requiring large assets to maintain. The paper also studies current research in micro mobile communication networks that have been growing exponentially in the past year including a host of different network types: ad hoc, smartphone, access point, sensor, etc. The paper lays out a solid understanding of all layers of wireless networking and the interactions between them (including physical, data link, medium access control, routing, transport, and application). The topics of security, efficiency, mobility, health risk, scalability, and their unique characteristics in wireless networks are discussed. Finally, the researcher explores advanced architectures, protocols, and satellite support for complex, dynamic, developing recursive network architectures, protocols, and looks at devices for complex, dynamic, high-performance communication in hostile and extremely remote locations such as the high sea.</td></tr>
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The opinions and conclusions expressed herein are those of the student author and do not necessarily represent the views of the U.S. Army Command and General Staff College or any other governmental agency. (References to this study should include the foregoing statement.)

ABSTRACT

MOBILE COMMUNICATIONS WITHIN THE DEEPWATER LIFELINES, by LCDR Franklin C. Kostenko, U.S. Navy, 124 pages.

This thesis researched the availability and applicability of using commercial off-the-shelf (COTS) cellular software and smartphone hardware platforms to address future individual communication requirements for the US Navy at sea. The paper presents evidence in favor of incorporation of COTS technology aboard ships to address tactical communications. Individual communication needs facilitated by devices include text, chat, voice, position location information, imagery and map viewing, streaming video, web browsing and e-mail. While all of these identified communication capabilities are currently available in military command and control systems, they presently reside primarily at hardwired workstations requiring large assets to maintain.

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Finally, the researcher explores advanced architectures, protocols, and satellite support for complex, dynamic, developing recursive network architectures, protocols, and looks at devices for complex, dynamic, high-performance communication in hostile and extremely remote locations such as the high sea.

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> But he said to me, “My grace is sufficient for you, for my power is made perfect in weakness.” Therefore I will boast all the more gladly of my weaknesses, so that the power of Christ may rest upon me.
>
> —2 Corinthians 12:9

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TABLE OF CONTENTS

Page

MASTER OF MILITARY ART AND SCIENCE THESIS APPROVAL PAGE iii

ABSTRACT iv

ACKNOWLEDGMENTS v

TABLE OF CONTENTS vii

ACRONYMS viii

ILLUSTRATIONS xii

CHAPTER 1 INTRODUCTION 1

CHAPTER 2 LITERATURE REVIEW 24

Cellular Communications Technology: It's History, Development, and Composition 24

CHAPTER 3 RESEARCH METHODOLOGY 51

Summary 60

CHAPTER 4 CASE STUDY FINDINGS 61

Conclusions of the NAVAIR Study 63
Cellular Communications Aboard Commercial Cruise Lines 67
Developing Smartphone Apps Suitable for the USN 72

CHAPTER 5 CONCLUSIONS AND RECOMMENDATIONS 84

APPENDIX A CELLPHONE SAFETY RECOMMENDATIONS 94

APPENDIX B CONSENT FOR PARTICIPATION IN RESEARCH INTERVIEW 96

APPENDIX C NETWORKS AT SEA INTERVIEW QUESTIONS 98

REFERENCE LIST 101

ACRONYMS

3M	Maintenance and Material Management
4G LTE	Fourth Generation Long Term Evolution
4G	Fourth Generation
AIS	Automatic Identification System
API	Application Programming Interface
ARCIC	United States Army Capabilities Integration Center
ARG	Amphibious Readiness Group
ARPA	Automatic Radar Plotting Aid
BYOD	Bring Your Own Device
C4I	Command, Control, Communications, Computers and Intelligence
CDMA	Code Division Multiple Access
CIO	Chief Information Officer
COTF	Commander of the Operational Test and Evaluation Force
COTS	Commercial Off-The-Shelf
CSDA	Connecting Soldiers to Digital Applications
CSIAS	Cyber Security Information Systems Information Analysis Center
DNA	Deoxyribonucleic Acid
DOD	Department of Defense
DON	Department of the Navy
DSP	Digital Signal Processor
ECDIS	Electronic Chart Display and Information Systems
EMF	Electromagnetic Field
EPA	U.S. Environmental Protection Agency

ESN	Electronic Serial Number
FCC	Federal Communications Commission
FDA	United States Food and Drug Administration
FFC	Fleet Force Command
FM	Frequency Modulation
GIG	Global Information Grid
GNSS	Global Navigation Satellite Systems
GPS	Global Positioning Systems
GSM	Global System for Mobile Communications
GUI	Graphical User Interfaces
HSPA	High Speed Packet Access
HYDRA	Hierarchical Yet Dynamically Reprogrammable Architecture
IC	Intelligence Community
ICT	Information and Communications Technology
IM/IT	Information Management/Information Technology
IMTS	Improved Mobile Telephone Service
iOS	iPhone Operating System
IP	Internet Protocol
ISO	International Organization for Standardization
LOS	Line-Of-Sight
Mb/s	Megabytes Per Second
MCP	Maritime Communication Partner
MIN	Mobile Identification Number
MTS	Mobile Telephone Service
MTSO	Mobile Telephone Switching Office

NCL	Norwegian Cruise Lines
NCW	Net Centric Warfare
OHA	Open Handset Alliance
OLS	Opportunistic Localization System
ONI	Office of Naval Intelligence
OS	Operating System
PDA	Personal Digital Assistant
PDR	Pedestrian Dead Reckoning
PNT	Positioning, Navigation, And Timing
PSTN	Public Switched Telephone Network
RAD	Reducing Administrative Distractions
RADAR	Radio Detection and Ranging
RCL	Royal Caribbean Cruise Lines
RF	Radio Frequency
RIM	Research In Motion
RMS	Royal Mail Ship
ROM	Read Only Memory
SAR	Specific Absorption Rate
SATCOM	Satellite Communications
SCRM	Supply Chain Risk Management
SDK	Software Development Kit
SID	System Identification Code
SOAR	State-of-the-Art Reports
SONAR	Sound Navigation and Ranging
SURFLANT	Surface Force Atlantic Fleet

TDD	Time Division Duplex
TDMA	Time Division Multiple Access
TD-SCDMA	Time Division Synchronous Code Division Multiple Access
UMTS	Universal Mobile Telecommunications System
USA	United States Army
USG	United States Government
USN	United States Navy
WCDMA	Wideband Code Division Multiple Access
Win EC 5	Windows Embedded Compact 5 Operating System
WP8	Windows Phone 8
WWAN	Wireless Wide Area Network

ILLUSTRATIONS

Page

Figure 1. Data Analysis Process..62

Figure 2. Schematic WLAN..70

CHAPTER 1

INTRODUCTION

> Over twenty five years ago in a speech at Moscow State University, President Ronald Reagan noted the implications of the global information grid of communication technologies: “Linked by a network of satellites and fiber-optic cables, one individual with a computer and a telephone commands resources unavailable to the largest governments just a few years ago . . . Like a chrysalis, we’re emerging from the economy of the Industrial Revolution.”
>
> —Ravitch, “Ronald Reagan Speech”

The purpose of this study is to explore the use of commercial off-the-shelf (COTS) cellular smartphone hardware and software to address individual communication needs on large-deck U.S. Navy (USN) ships deployed at sea. At the time on Reagan’s speech the computer and telephone were separate tools, todays the smartphone is both combined, now one and the same. The majority of past studies on individual communications technologies aboard naval ships centered on either COTS cellular software specific to an application (Navy Individual Augmentee 2013), or on the utility of tactical communication devices, including handheld radios, as they are currently employed at sea and on land (Naval Technology 2012). The intent of this study is to explore the possibility of replacing the current Hierarchical Yet Dynamically Reprogrammable Architecture (HYDRA) system[1] supplied by Harris Radio with newer COTS cellular smartphone hardware and software technology while continuing to satisfy

[1]HYDRA is a Wireless Interior Communications System that uses portable radios and low power base stations to enable shipboard communications. Maritime Damage Control and Personal Protective Equipment Information Center 2013, “HYDRA wireless interior communications system,” U.S. Navy, http://www.dcfpnavymil.org/ Systems/Communications/hydra.htm (accessed 17 November 2013).

communication and information distributional needs for companies of USN ships in a tactical shipboard environment. The challenge is to provide a number of viable COTS technology options to enable contact and communications among sailors at the deck plate level. Functions provided by commercial smartphones and other personal network devices that include text and voice messaging, global positioning system information (GPS), imagery and map viewing, video streaming, web browsing and e-mail access. Using COTS technology, the USN should be able to incorporate into its communication systems the latest mobile computing systems already used in large-scale retail complexes, theme parks, airports, and megamalls (Crockett 2013).

Handheld radio units are pervasive throughout the military command and control systems of the US service branches, but these devices require the establishment and maintenance of large communication infrastructures, and most only have a basic voice capability. Following recent advances in current COTS smartphone technology and in the global commercial cellular industry, this study explored the possibility of using COTS solutions for deployed sailors operating in non-littoral (blue water operations) environments.

Currently, US Navy sailors are not permitted to use private cellular phones while ships are underway; nevertheless, many still do. When the ships are operating near the shoreline (the littoral zone or close to the shore), especially in heavily populated coastal cities such as Seattle, San Diego, and Miami, mariners can receive a terrestrial cellular signal to about ten nautical miles off the coast. Many maritime communities, such as Key West or the Straits of Juan de Fuca, are already deploying cellular towers on navigational buoys, thus extending terrestrial cellphone reception to over sixty-five miles off the coast (Rystrom 2013).

Understandably, before cellular technology and smartphones are incorporated into a Department of Defense (DOD) command and control suite, they must first overcome Command, Control, Communications, Computers, and Intelligence **(**C4I) roadblocks. These potential roadblocks include current DOD and Department of Navy (DON) polices regulating cellular use, network security, and device and software accreditations. This study seeks to provide a greater understanding of the potential benefits leveraging COTS cellular technology to provide an enhanced command and control system beyond HYDRA in light of the USN's objective of creating a new Network Centric Warfare (NCW) architecture at a lower cost to the US taxpayers.

Just after the turn of the twentieth century, one of the most renowned shipping tragedies of all time occurred in the Atlantic Ocean. On April 15, 1912, the *RMS Titanic* sank on her maiden voyage from Southampton, England to New York City. The *Titanic*, the world's largest passenger steamship at that time, struck an iceberg four days into the crossing and sank to the ocean floor taking 1,517 lives (approximately two thirds) of the 2223 passengers aboard (Mersey 1915).

The sinking of the *Titanic* may be attributed, in large part, to a massive communications failure; the leadership intentionally ignored reports of large icebergs in the shipping lanes. In the aftermath of that tragedy, the maritime industry and the USN have actively endeavored to improve safety. It is no exaggeration to say that ships in 2013 provide a far safer form of transportation for passengers, cargo, and seafarers than they did in 1912; however, significant challenges in sea going communications remain.

The more recent wreck of the Carnival Lines *Costa Concordia* provides a case in point. In 2012, the ship struck a reef near Giglio Harbor on the Italian coast and sank resulting on 32 deaths. The cause of the ship's loss was blamed on both a judgment error by the ship's captain as well as several ship wide communications breakdowns. What is especially interesting for this study is that most of the three thousand or so remaining crew and passengers were rescued specifically due to the use of cellphone calls seeking help. At the same time, some of the ship's crew attempted to attenuate negative publicity by telling the Italian Coast Guard that they were fine and the passengers were just overreacting.

Maritime safety affects everyone—including our military. The global population depends on a safe and efficient shipping system to meet high, modern-day standards. In the 100 years since the loss of the *RMS Titanic*, the maritime industry has worked steadily to improve safety performance so that the twenty-six million tons of cargo and 80,000 cruise passengers that travel by ship every day, do so safely and efficiently (Rossignol 2013).

Low operational costs are the principal reason for the high level of efficiency achieved by modern shipping vessels today. Maintaining these low costs requires keeping ship crews as minimal as possible, as labor costs are the highest single operating costs of global shipping operations (Maritime Administration 2011). Keeping shipping crews to a minimum, however, does not allow for very much leeway in terms of human fatigue or the inevitable extra tasks that 24-hour operations sometimes require when an unexpected emergency arises. The inevitability of fatigue under the pressure of an around-the-clock work schedule poses a potential cause of accidents that maritime experts have identified as a risk-management challenge.

Long and irregular work hours are not the only risks to shipping operations. Piracy continues to threaten shipping and occupy USN rescue missions. In the small region of the Straights of Malacca and the Horn of Africa, off of Somalia, thirty-one ships were attacked by organized Somalian pirates in 2011 at a cost of over $7 billion; and thirty-two more were attacked in 2012 at a cost of $10 billion in 2012 (Bockman 2012). Furthermore, individual communications challenges exist on merchant vessels and cruise lines in the form of spoken language barriers adding potential risks, given the dependence on English as the "language of the seas" (Maritime and Coastguard Agency 2013). With increasing globalization of trade has come multinational ships crews, and with these crews concern has been raised within the maritime industry about deep-water communication in an emergency, or even misunderstandings during routine sea going operations.

There are other risks at sea of unknown scale and potential. In extremely hostile Arctic and Polar waters, global climate change is opening up access to previously impassable seaways. In the development of routes through the North East Passage, for example, ship crews face new challenges in iceberg navigation, environmental impact, future construction demands, and emergency communications procedures. Fire remains the major on-board risk especially on passenger ships with increased hotel services and very large numbers of passengers and crewmembers aboard.

The Department of Navy (DON) already uses a variety of commercially available wireless products to meet much of its on-shore enterprise mobility needs. Naturally, as technology advances, the Navy will incorporate these products to enhance individual communication at sea, as the private shipping industry is currently doing. Mobile media devices today include cellphones, personal digital assistants (PDAs), BlackBerry® smartphones, “wearable’s” (e.g., smart watches and Google Glasses), laptops with wireless fidelity (Wi-Fi), Bluetooth, air access cards, sensors, and/or Radio Frequency Identification (RFID) communication systems. As advances in microchip technology incorporate more power and functionality into smaller and smaller devices, these mobile devices will become increasingly important in delivering enterprise mobility. Using commercial wireless products at sea will also enable standardization and interoperability across the USN. Additionally, advantages will be realized in spectrum utilization and cost efficiencies.

The DOD has used BlackBerry smartphones for a number of years on land. There are also other independent efforts underway to explore viable ways COTS technology can be employed in the DOD, such as Connecting Soldiers to Digital Applications (CSDA) (Bague 2010). This effort is headed by the U.S. Army‘s Capabilities Integration Center (ARCIC) and the Army‘s CIO/G6, with support from Army Training and Doctrine Command (US ARMY CIO/G6). The purpose is to test the applicability and utility of employing cellular COTS technology to enhance the situational awareness of soldiers in the field. The incorporation of smartphone technology into the US military and related topics were explored in detail at the US Military Smartphone Handheld Device conference of October 2013 in Washington DC.

Technology has been a key driver of safety and productivity, from the introduction of gyrocompasses and the first use of aviation to spot icebergs and other hazards in 1914 to the mandatory use of Electronic Chart Display and Information Systems (ECDIS) in 2012 supported by space systems. Military innovations continue to drive improvements in global transportation and communications for example in radar and in wireless communications, while later technologies such as Automatic Radar Plotting Aid (ARPA), Global Positioning Systems (GPS) and Automatic Identification System (AIS), have reduced accidents through greatly improving situational awareness via increased access to real time navigational information (National Coordination Office for Space-Based Positioning, Navigation, and Timing 2006).

In addition, search and rescue efforts have been greatly assisted by modern (satellite-assisted) location-finding technologies such as radar transponders and broadcast distress beacons. Maritime experts have warned of dependence on single technologies, citing examples where reliance on a single technology has led to major incidents (Fichman 1992). Improvements have also stemmed from changes in construction and design processes. Ship building techniques, such as prefabrication and welding, have improved quality and structural integrity, while computer aided design has radically sped up the design process, allowing modeling to replace physical trial and error (Allianz Global Corporate and Specialty 2012). Individual communications via smartphones at sea is the next step on the ladder of progress. This approach seeks to leverage the technological advances and cost savings now found in the private, corporate, and individual consumer sectors.

Some questions raised in this discussion are:

1. Can smartphones using commercial off-the-shelf (COTS) cellular software and hardware address individual communication and information needs at sea?
2. What is the current shipboard individual communicator (HYDRA) requirement?
3. What are the current limitations?
4. What benefits can shipboard indoor mapping services and global positioning services provide the USN for sailors while at sea?
5. How much of the world's oceans are under satellite coverage capable of providing global information grid (GIG) connectivity?
6. What are the security concerns with using COTS technology for military application at sea?
7. Are iOS or Android systems better for future networks at sea?
8. What is the best method of base-station node (hot spot) distribution on ship?
9. At what range may ship cell networks switch to terrestrial cellular stations?; and
10. What is the upper limit for individual handsets connecting to a ship via a Wi-Fi or Bluetooth type network?

Cellular phones are now in common use and one can assume that almost every person employed by the USN will have a networked capable smartphone in his or her possession in the very near future. This assumption also appears to have been made by industry. Thus, we are seeing an increase in the development of indoor mapping and commercially available mobile computing applications including smartphones, wireless mobile phones connected to mobile operating systems, and more advanced computing capability connectivity than has ever existed before. This system is referred to as bring your own device (BYOD).

The first smartphones combined the functions of a personal digital assistant (PDA) with a mobile phone (Rystrom 2013). Smartphone models have also added the functionality of portable media players, digital cameras, compasses, stopwatches, video cameras, audio recorders, Global Positioning System (GPS) navigation units, security identity systems, document scanners, and voice activated computers to form one multi-use “Swiss-Army-Knife” type device (Crockett 2013). Most modern smartphones also include high-resolution touchscreens and World Wide Web connectivity. High-speed data access is provided to handheld mobile units today by way of microwave radio frequency (RF) signal, Wi-Fi, Bluetooth and/or other mobile broadband systems.

Because cellular and smartphone technology is evolving so rapidly, it was not possible, nor practical to rely solely on published information that is likely to be superseded by more current information soon after publication. In this sense, the study could only rely on the literature review for archived, historical technology information. Instead, data from Office of Naval Intelligence (ONI) officers and private industrial shipping sources were accessed to bring the paper up-to-date and conversant about the most current mobile technologies. These sources provided valuable information about the technology. They also revealed the current attitudes about the usefulness in practice of this technology from users who have attempted to achieve the most cost effective individual communications at sea.

The Navy currently uses the HYDRA system for individual communications on large deck ships such as the aircraft carriers and amphibious assault craft platforms. The HYDRA handset resembles a two-way radio. Although the Harris Corporation, which builds and installs these radio systems, advertises an additional functionality of the HYDRA also includes file sharing and image transfer, in practice, the radio voice function is the feature in common use by sailors (Hill 2013). Moreover, the system is complicated and not user friendly–sailors may only use the radio feature at sea. A large part of the shipboard requirement is focused on the flight-deck operations and the platforms support–as any airport would require for complicated aeronautical support operations.

COTS smartphone technology could meet the doctrinal requirements as currently set out in Navy operational requirements document serial number 430-06-96, dated March 2, 1996 (Appendix D). A COTS smartphone option could bring additional services to the individual user, in addition to the simple voice feature required according to current Navy doctrine.

As technology advances and costs of hardware, software and the network infrastructure come down; it is likely that application of a flexible smartphone system will be the most productive, cost effective way ahead. Communications at sea today also rely on overhead satellite support when communication must take place over the horizon, out of the line of sight. The DON has access to a robust constellation of communication satellites that currently cover 100percent of the world’s oceans (Page 2013). The COTS option also brings into play several redundant commercial communications satellite constellations that currently cover 90percent of the world’s oceans. When the iridium network of commercial satellites is operational, the coverage theoretically jumps to 100percent of the planet (Rejan 2007).

Security is a concern to any network, especially a wireless one. One document that has a great comprehensive examination of the current state-of-the-art cyber security is the “Risk Management for the Off-the-Shelf Information Communications Technology” published in late 2010 by the Cyber Security and Information Systems Information Analysis Center (CSIAC). This document focuses on supply chain risk management (SCRM) as it pertains to Information and Communications Technology or (ICT). This State-of-the-Art Report (SOAR) investigates the groundbreaking developments in contemporary information assurance (IA) issues. It includes how information technology SCRM emerged as a major concern within the DOD, the intelligence community, and even civilian government, and it describes the numerous threats to the ICT supply chain.

This examination covers from the ICT supply chain itself to the hardware and software products within it. It discusses current and emerging safeguards and countermeasures against threats as well as mitigations to supply chain vulnerabilities to those threats. The main focus of the SOAR is its comprehensive survey of government, industry, and academic activities and initiatives (in the United States and abroad) that address various aspects of the SCRM challenge, including scientific and technical research to further available techniques and technologies for increasing the robustness and resilience of the supply chain against the security threats that target it (Cyber Security and Information Systems Information Analysis Center 2010).

Every digital cellular device contains the same basic components, including a circuit board containing the “brains” of the phone, an antenna, a display screen, a keyboard, a microphone, a speaker, and a battery (Agar 2013). The circuit board is comprised of several chips and controls the system. The analog-to-digital and digital-to-analog conversion chips translate the outgoing audio signal from analog to digital and the incoming signal from digital back to analog. The digital signal processor (DSP) is a highly customized processor designed to perform signal-manipulation calculations at high speed. The microprocessor handles all the functions of the keyboard and display, deals with command and control signaling with closest the base station, and coordinates the rest of the functions on the motherboard (Farley 2007).

Cellular smartphones provide an incredible array of functions (Rystrom 2013). Depending on the cellphone model, one can:

1. Store contact and data information on the units memory;
2. Create task or to-do lists on calendars;
3. Schedule appointments and set reminders;
4. Utilize the built-in calculator for math;
5. Send or receive e-mail;
6. Obtain information (news, entertainment, stock quotes) from the Internet;
7. Play games;
8. Listen to music;
9. Watch TV, and movies;
10. Read books and magazines;
11. Send and receive text messages;

12. Communicate in real time using a video camera (e. g., via Skype);

13. Record and photos, video or audio content;

14. Transmit and receive this recorded content;

15. Integrate other devices such as PDAs, MP3 players and GPS receivers.

The physical features of the hardware support functional aspects of the software. Some additional basic parts inside every digital cellular smartphone include:

1. a circuit board containing the "brains" of the phone
2. an antenna
3. a display screen
4. a keypad, keyboard, or touchscreen
5. a microphone
6. a speaker
7. a battery
8. an interface for a power supply or charger
9. memory chips

The circuit board is comprised of several microchips and controls the unit. The analog-to-digital and digital-to-analog conversion chips translate the outgoing audio signal from analog to digital and the incoming signal from digital back to analog. The digital signal processor (DSP) is a highly customized processor designed to perform signal-manipulation calculations at high speed. The microprocessor handles all the functions of the keyboard and display, deals with command and control signaling with the base station, and coordinates the rest of the functions on the board. The Read Only Memory (ROM) and Flash Memory chips provide storage for the phone's operating system and custom features, such as the phone directory. The Radio Frequency (RF) and power section handles power management and recharging, and processes the hundreds of available frequency modulation (FM) channels. Finally, the RF amplifiers handle signals traveling to and from the antenna (Barnes and Meyers 2012).

The display has become larger to accommodate the increasing number of features and applications being performed by cellular smartphones. The majority of phones incorporate some form of personal digital assistant (PDA) or web browser. Some phones store certain information, such as the System Identification Code (SID) and Mobile Identification Number (MIN) codes, and internal flash memory, while others use external cards. Finally, cellular phones incorporate extremely small speakers and microphones.

One of the distinguishing features of a smartphone is its advanced and easily updatable operating system. With an advanced operating system, smartphone devices are capable of operating at an equivalent or even better speed when compared to Windows or Mac OSX on a desktop computer. Factor in the virtually infinite possibilities for customization with applications (apps), form-factor size, and relatively intuitive ease of use; it is not surprising that demand for smartphone technology continues to skyrocket today. Aside from the advanced operating system that forms a layer of interaction between the phone's hardware and application, smartphone developers have developed features that allow the phone to discover and provide recommendations to the user. For example, a basic phone might allow users to utilize a browser to access e-mail once configured to do so, whereas a smartphone can utilize the same functions based on the user's e-mail identification (Sahil 2010).

Advancements made with operating systems have enabled the smartphone to run productivity applications (Apps) such as spreadsheets, word processors, and graphics programs. However, there are multiple manufacturers, vendors, and carriers that offer consumers a large pool of smartphone devices from which to choose, there is a relatively much smaller pool of options regarding smartphone operating systems. That is, there are a number of different mobile devices running the same basic smartphone operating system (Sahil 2010).

To the common user, a smartphone's operating system (OS) may not be a significant deciding factor when purchasing a new phone, especially when compared with hardware and user interface (visual appearance and functionality) options. While the OS of any particular smartphone does play, a significant role in the device's functionality, tailored functionality is also heavily dependent on the availability of applications that can enhance the personalization of the device to its user. One of the crucial elements for a successful smartphone equivalent for the armed forces is the ability to run complex applications that serve the unique needs of military service members. It is also imperative that the smartphones are capable of running on the military's secure networks to protect information.

Making a decision about the smartphone and smartphone operating systems that would be the best match for integrating smartphone technology into the everyday communications repertoire of the US Navy requires analysis of the smartphones already available on the market today, the wireless technology required to sustain or facilitate communication on those devices, the upgrades required to make the device secure, and the cost of all options. Below are manufacturers and characteristics of the industry's leading smartphone OS’s. While many options are available worldwide, these manufacturers and their OS’s are the industry’s most prominent choices.

Derived from the Mac OS X system used on Macintosh (Mac) computers, iOS is Apple’s mobile OS for mobile phone devices. The Unix-like operating system, using an aqua theme with its Graphical User Interfaces (GUI) was first introduced on Macintosh desktop computer systems in 2001. The most recent release of Apple’s smartphone product line, the iPhone, running on the iOS platform was released in late September of 2013.

The programming language used to develop iOS is named Objective-C. Objective-C is a type of object-oriented programming language that enables sophisticated programming via a relatively simple programming language (Apple 2013). The iPhone was one of the first devices to incorporate a multitouch screen in place of the traditional keypad, and its launch was met with strong consumer demand, selling 1,120,000 iPhones in fiscal year 2007 (Apple 2007).

Depending on the version of iOS used (system 7.0.4 is the most current); the iOS platform can operate in CDMA or GSM mode, giving global coverage flexibility to its users. Starting with music, Apple has ventured into cloud-based customer services; this gives the industry some idea of the relevance of cloud services (Apple 2013). Using Apple’s iPhone Applications store, users can find over 500,000 applications that add to the robustness of a user’s iPhone (Apple 2013). A major point of contention between applications available in the Android and Apple marketplaces is the proprietary nature of Apple products. In some cases, Apple simply chooses not to offer compatibility with programs like Adobe and Silverlight, which make video streaming possible on sites like

Hulu and Netflix. While these two programs may not be essential–or even relevant–to the use of smartphones for maritime vessel sailors, it may be a symptom of a larger problem–a company unwilling to accommodate open source or cross-market applications.

New research has shown that the newest iPhone models are more likely to break than any of the other options on the market (D'Innocenzio 2013). While this may present a problem for the average consumer, military phones are routinely upgraded with extra physical protection before being issued to personnel, which may offset the phone's normal fragility. Apple is currently offering a commercially more durable iPhone for an additional fee.

The most recent successor to Microsoft's mobile device OS platform line, Windows Phone 8 (WP8), built on Microsoft's C# programming language, was released in the United States November 4, 2013. Microsoft, which has traditionally followed product-line evolution with its PCs, tablets and pocket PCs, scrapped the old Windows Mobile platform that was based on Windows Embedded Compact 5 OS (Win CE 5). The older platform was a component-based, embedded, real-time operating system. The major differences between Win CE 5, CE6 and Win CE 6 are that the Win CE 7 and newest WP8 kernel layout supports the file system, the bulk of its drivers, the Graphics Windowing and Events Subsystem (GWES). These and other features have led to a significant reduction in system overhead for the OS. WP8's programming is conducted using shared-source and can be done in any language that uses the .NET managed code framework, yet coding must be done through Windows Mobile Software Development Kit (SDK). In terms of applications available in the Microsoft marketplace, the company seems to fall behind when compared to options offered by other countries. For one, official applications that are available in the Google marketplace are not available in the Microsoft marketplace as of 2013 (Microsoft News Center 2013).

A member of the Open Handset Alliance (OHA), Google's Android OS was first released in September of 2008. The Android OS is based on the Linux kernel consisting of an open-source software stack that includes an OS, middleware and other key applications. The most current Android version 4.3 arrived in the United States on 24 July 2013. The significance of it being an open-source platform is that any developer can access the same framework of Application Programming Interface (API) that is used by its core applications (Rystrom 2013). The intent is to enable Android developers (anyone who can write code) to build innovative applications by allowing them access to its application coding review and component reuse (Metz 2010). This may make the Android system the most flexible to work with in terms of developing new applications for naval and military use, as there is a substantial body of code to use as a starting point for the development of new applications.

Code developers can use the Android software development kit for developing new applications, which dramatically increases the potential for customization and adaptation of smartphone technology to the specific needs of a military operation or maritime vessel. The Java programming language is the primary language used for Android application development. Some key capabilities and traits of the Android OS are robust multitasking, greater hardware options, (the OS is not tied to any one manufacturer or brand name) directly translating to more service carrier options, and Read Only Memory (ROM) customization (Escallier 2010). The latest version of the Android OS is Android 4.4.0, which can be found running on a host of devices and depending on which model some can operate in Global System for Mobile Communications (GSM), Code Division Multiple Access (CDMA) or both. With the open-source development strategy, unknown numbers of programmers continue to create and refine Android applications; Google reports there are over 1,500,000 applications available in the Android Market.

The U.S. military already has some experience with Google's OS–in 2011, the Department of Defense began developing a smartphone equivalent called a Joint Battle Command-Platform, designed to replace smartphones for active duty military members (Kenyon 2012). This device, unlike commercially available smartphones, is designed with security features that keep information secure from non-military sources. Because the Joint Battle Command-Platform was designed to run Android or parallel software, the possibilities are limitless–an application can be designed to meet virtually any need of service members and run on a secure military network. At the end of 2012, Android products made up more than 65percent of the smartphones and tablets sold (Takahashi 2012). With more and more government agencies choosing Android-based devices for staff members, it seems increasingly likely that Android smartphones will make an appearance gain a foothold on maritime vessels.

Designed and developed by Research in Motion (RIM), its first device was a two-way pager launched in 1999. Depending on the device model, the BlackBerry phone can operate in either GSM or CMDA, providing its user with greater geographic flexibility. The current OS for BlackBerry is OS 10, but there is speculation that the soon to be released BlackBerry OS 11 will have devices that may run on a High Speed Packet Access (HSPA) variant that extends and improves the performance of existing Wideband Code Division Multiple Access (WCDMA) protocols (Rouse 2005).

While older versions of the OS platform were based on C++, for its newer versions RIM fully supports the use of Java 2 Platform, Micro Edition (J2ME) (Qusay 2005). The newer BlackBerry OS platform also supports Java's Mobile Information Device Profile (MIDP) for embedded devices. A number of carriers offer BlackBerry devices; however, all of its devices are linked to RIM's Network Operations Center (NOC), which directly connects to BlackBerry's Enterprise Servicers (BES) located worldwide (Computer Doctors of South Florida, 2013). The BlackBerry App World is RIM's repository where users can find BlackBerry applications.

Traditionally, BlackBerry devices that received authorization for military use were devices that could only support email and limited Internet use–rather than devices that could support interactive applications contributing to the success of a maritime mission (McInnes 2011). Receiving authentication for applications as well as e-mail is a more difficult task for technology companies because of the complex nature of data transmittal via applications on a smart phone, but remains possible. For years, Blackberry devices composed almost 475,000 of the 600,000 smartphones used by military and defense personnel (Niu 2013).

Over the past two years, government agencies and the Pentagon have increasingly dropped their contracts with RIM in favor of contracts with other carriers that offer iPhones, apparently due to the unreliability of the purchased BlackBerry models that personnel had used in years past. The latest version 10 was realized on January 30, 2013, with little success at capturing the market share (Goldman 2013). Recently the National Transportation Safety Board released a statement noting that the decision to switch from BlackBerry devices to iPhones was motivated in large part to the increasingly often failure of BlackBerry devices. An “unacceptable rate” of failure in BlackBerry devices used on land and surrounded by reliable network connections makes it difficult to argue that these Blackberry devices would be a good fit for a much more tenuous situation in terms of stability and network availability (TEKConn 2012).

This research has demonstrated the potential cost savings and operational benefits to current U.S. Navy operations that individual cellular COTS communications at sea can provide. As the United States Government (USG) has sought to save money and the USN has expressed its intentions to increase the quality of its purchasing power, the potential benefits of using COTS commercial services is very compelling. Comparing the wireless service/options, infrastructure and cost structure that have just become available on commercial cruise ships in 2013 to communications systems currently available on USN vessels has demonstrated what is possible when ships are outfitted for wireless internet and smartphone services via ship wide Wi-Fi at sea.

This study has presents a tremendous opportunity to learn from the experience of others how well these new communications systems perform with minimal investment. Access to personal communications at sea is not simply a means of entertainment that serves merely to increase a passenger’s or sailor’s morale, it may also prove critical for safe operations, ship maintenance, successful missions, unbroken status reports and even emergency communications.

Military leaders have worked for decades to better define and utilize the potential power available to the military through information technology (IT). This IT edge is what has propelled firms today such as Wal-Mart, Google, and Amazon to retail leaders. What can be seen now is a telecommunications network of links, technologies, and capabilities that facilitate command, control, communications, information sharing, data analysis, collaborative efforts, situational awareness, synchronization, and integration across the armed forces. The GIG network provides an enabling capability, as technology continues to rapidly develop that can be fundamental to truly operationalizing the potential of design methodology, mission command–achieving organizational adaptation and continuous strategic, operational, and tactical advantage for USN Ships at sea (Department of Defense 2005).

Rear Admiral Herm Shelanski, the director of the Navy's Assessment Division who is overseeing the Navy's Reducing Administrative Distractions (RAD) campaign, views smartphone and tablets at sea as "a way ahead" but said he does not know how quickly the incorporation of this technology could come to fruition (Fellman 2013). Navy leadership launched a Navy-wide innovation experiment July 2013, asking sailors and civilians to report the biggest time-wasters and then collaborate on ways to fix them. Repeatedly, they heard complaints about maintenance and material management (3M). This scheme of checks, paperwork and spot-checks consumes millions of sailor hours every year across ships, squadrons, shops and submarines, not to mention millions of pages of paper and countless amounts of printer toner.

Shelanski sees overhauling this 'headache-inducing scheme' as his task force's primary mission. Fixing it will require cooperation between bureaucracies and new technologies all now within reach because of devices such as smartphones and iPads, which could also improve training and communications across the fleet. "I think it's a process that has kind of stagnated over the years, and it's just ripe for modernization, digitization," Shelanski said in a September interview (Fellman 2013). The RAD campaign’s vision includes issuing an unspecified type of tablet computer to every work center and division–in other words, to tens of thousands of sailors in the fleet. The tablets could streamline all general military training. New lectures and updates could instantly be sent to even the fleet’s most far-flung corners of the ship.

CHAPTER 2

LITERATURE REVIEW

Cellular Communications Technology: Its History, Development, and Composition

Formal, written, current primary source information about COTS technology and the official use of cellphone technology on USN ships was found to be scant due to the newness of this technology. The USN has not yet installed COTS technology on USN warships, nor is there an official policy to do so in the works, although there have been on-going exploratory talks and investigations.

Primary written source material is available for recent sea trials conducted on *USS Kearsarge, USS San Antonio,* UH-IN helicopter and satellite communications (SATCOM) coordinated by Fleet Forces Command aboard the limited fleet Amphibious Readiness Group (ARG) (Global Cyber Network Staff 2013). There is a historic secondary source of naval doctrinal material (Department of the Navy Chief Information Officer 2008 and Department of Defense Chief Information Officer 2013) as well as information on radio communication equipment aboard most USN vessels (Harris 1996).

Secondary sources available via the internet include news reports, technical papers, marketing materials, and industry white papers. These include reports about systems recently installed on commercial cruise ships written by manufacturers of the COTS equipment. However, for the most part the information is too new to have been written about in books, formal reports, or many academic studies.

In place of published articles, the principal source of primary source information used in this study was collected through direct interviews, e-mails, and telephone conversations with official USN personnel, representatives of commercial cruise ships, and vendors providing cellular and satellite receiving equipment to commercial cruise ships. These interviews enabled the researcher to obtain valuable subjective feedback about the current situation and state-of-the-art of exploratory efforts underway.

Because of the limited amount of material available, this chapter is used to describe the context of cellular communications technology–its history, development, and composition.

In keeping with the theme of the U.S. Navy's Enterprise mobility 2008 produced by the Department of the Navy Wireless Working Group for the USN's Chief Information Officer (CIO)–the ability to provide Sailors and Marines with the information they require as they move between office, garrison, sea and battlefield or ad hoc locations–is a critical component of the Department of the Navy's efforts to support the troops and those who support them. Enterprise mobility represents the last link in the network that provides sailors with the 'power to edge' component of net-centric warfare (NCW); indeed, without this capability NCW would be impossible.

In addition to customized military-specific solutions, DON has considered a variety of commercially available wireless products to meet much of its enterprise mobility need leveraging the intensely competitive research invested in by private industry. There are significant advantages to this approach. Adopting commercial products would:

1. assist in standardizing equipment;
2. provide interoperability across the DON as well as with joint and coalition forces;

3. allow the DON to take advantage of the research and development of the commercial sector;
4. provide a ready-made near-global network supporting voice and data;
5. preserve the increasingly precious spectrum assigned to the DON through the use of shared, unlicensed frequencies; and
6. be more cost effective than building customized wireless solutions.

At the same time as providing significant advantages, all wireless technologies have inherent drawbacks and resultant concerns. Chief among these concerns, of course, is the security of the signal as it traverses the airways (Allied Business Intelligence Research 2013). Another significant concern is the potential for a wireless platform to introduce new radio frequency emanations into a military environment where they might have an impact on weapons systems (Kuznetsov and Puri 2013). Implementation of wireless technologies cannot go forward until these and other potential drawbacks are satisfactorily addressed. Enterprise Mobility (2008) described the strategy the DON is following in assessing and adopting commercially available wireless products to enhance its enterprise mobility capability.

Program managers as their projects progress will develop specific program time lines and milestones as appropriate. Robust, secure, and ubiquitous access to the required information will also be provided through the development of an enterprise mobility capability that incorporates commercially available wireless products and solutions (Motorola 2013). The end-state capability to realize this vision will utilize ‘smart’ devices in the field that automatically sense networks, devices and users and configure themselves to deliver the right information to the user through the best network option available, including, if necessary, connecting to other smart devices within range. Solutions will range from simple ones implementing one device and technology to more complex networks where a variety of devices and technologies will operate in concert under a ‘bubble’ of wireless connectivity (Toh 2001).

The Department’s vision for enterprise mobility aligns with and complements existing and planned Department of Defense (DOD) and DON Information Management/Information Technology (IM/IT) telecommunications and spectrum management initiatives. This vision for enterprise mobility includes data, video, and voice capabilities. Through the DON Wireless Working Group, the department is working to align resources, personnel, and processes to achieve this vision and end state (Department of the Navy Chief Information Officer 2008). The net-centric environment of the Global Information Grid (GIG) will provide our troops with Information Superiority, affording decision superiority, tactical advantages and enabling mission accomplishment. To maximize these benefits, information must be available where the troops and those who support them are located—even if no traditional, wired network infrastructure is in place.

The ever-advancing capabilities delivered in commercially available wireless technologies present the DON with opportunities to expand secure information access to the members in locations where previously, such access would have been impossible or impractical. The Enterprise Mobility (2008) report describes the process the DON would like to use to leverage the significant advantages these technologies can deliver while ensuring required levels of Information Assurance and performance. As this report highlights, the DON has already made great strides in making information available to those who need it, where they need it, and our enterprise mobility capability will continue to be enhanced on an ongoing basis (Kenyon 2009).

A wireless communications system, like many other technological advances, was originally invented as a contribution to warfare. Although Mobile Telephone Service (MTS) introduced the first cellular phone service in 1949, the beginnings of this technology may be traced back to ideas developed fifty-six years earlier in the 1880s. Italian physicist Guglielmo Marconi succeeded in transmitting wireless signals over a distance of one and a half miles in 1885, securing the first patent for a wireless telegraph system shortly thereafter (Garratt 1994). Marconi created the Wireless Telegraph and Signal Company a year later, while perfecting his new technology to be able to send wireless signals for a distance of twelve miles (Rossignol 2013).

A mere 15 years after his first wireless transmission, Marconi successfully transmitted wireless signals more than 2,000 miles from source to destination. In 1901, Marconi pushed the boundaries of human knowledge again by proving the curve of Earth did not affect the successful transmission of wireless radio waves. He demonstrated this by sending signals from Cornwall, England to St. John's, Newfoundland, a distance of over 2,000 miles (Rossignol 2013).

The first ship-to-shore radio voice conversation took place in 1922 from the *S.S. America* to Deal Beach, New Jersey–a distance of 400 miles (Aitken 1985). In 1932, the world's first microwave radiotelephone link was established between the summer home of Pope Pius XI in the Italian town of Caster Gandolfo and the Vatican City, a distance of approximately thirty miles. Intercontinental telephone communications between the United States and England occurred in the mid-1930s (Rossignol 2013).

Similar to countless other forms of technology that have been widely adopted for consumer use, cellphones were born, in their early form, out of a desperate desire to outpace German technological developments during World War II. As German forces perfected submarine communications, the U.S. Navy raced to develop technology of their own that would enable them to match German forces.

Martin Cooper, Motorola Corporation's visionary, gained his early experience with wireless technology as a submarine commander in the U.S. Navy (Leard 2008). The submarine squadrons of World War II provided valuable and convenient testing opportunities for wireless communications at sea. The Germans perfected the technology enabling their submarine fleet to lead all other nations in underwater navigation and communications between submarines.

Sonar, originally an acronym for Sound Navigation and Ranging, was a technological advance that came out of these circumstances. Sonar utilizes underwater sound waves that are sent out and returned to their origin after striking off solid surfaces. The speed with which they returned signals determines the distance and depth of the given object from the submarine.

Radio Detection and Ranging (RADAR) would come a short generation later; relying on the same basic concept out of the water that sonar had developed under water (Schram and Carlo 2001). Radar changed the world by making weather forecasting far more accurate, which made it possible for military forces to properly plan and adapt mission goals according to real-time situations on the ground (Buderi 1996).

Physicist Heinrich Hertz who began experimenting with radio waves in his German laboratory in 1887 discovered radar (Kostenko, Nosich, and Tishchenko 2003).

Hertz found that although radio waves could be transmitted through some materials, they would pass though others before bouncing back. The race to develop radar took off by the 1920s as Great Britain, Germany and the United States all competed to be the first to develop the technology (Buderi 1996).

In the United States, COL William R. Blair, US Army director of the Signal Corps Engineering Laboratories, was the first American to receive a patent for radar technology. In the United States, Blair was the first American to receive a patent for radar (Rejan 2007).

The public outcry that followed the sinking of the "unsinkable" *RMS Titanic* was a contributing factor to push for the discovery of the technology, pushing its transition from military into robust civilian use (*The New York Times* 1912). It took only twenty years before scientists around the world began to discover the practical use of radio waves to detect and locate objects such as icebergs, storms, and other obstacles at sea (Rossignol 2013).

In the cold, damp, and windy weather conditions of the open sea, sailors considered the warmth generated by the radar equipment as a benefit. This fact did not elude scientists, who utilized the heat generating characteristic of radar to develop the first microwave ovens, originally called 'Radar-ranges,' which heated food by sending wave lengths of 915 MHz, similar to many of today's cellular phones, through items placed in an oven enclosure (Ganapati 2010). In the beginning, some cellular phones relied on wavelengths similar to those used by earlier microwave ovens and primitive radar. The only measurable difference is the power (wattage) that is needed to operate radar in a microwave oven. Cellular phones send pulsed peak signals that operate on an average of about one watt (Marchetti 2010).

In 1946, the United States military achieved a breakthrough in the use of radar when soldiers at U.S. Army Camp Evans conducted an experiment aiming a concentrated high frequency ‘Diana’ radar beams at the moon. The beam took only two and a half seconds to produce an audible ping over their receiver loudspeaker traveling at the speed of light (186,000 miles per second). This ushered in the development of satellite communications and missile guidance systems that are now commonly in use (Schram and Carlo 2001). Near the end of World War II, military strategists pushed for the invention of small, lightweight warning systems. In order to fit radar and its antennas onto planes, scientists had to make them smaller and more portable. Since the interwar period before World War II, the American military has used advanced radar in every war, helping to protect soldiers, sailors, and civilians in the battle space, making air, and highway travel safer and faster, as well as predicting accurate weather forecasts.

Over time, development of wireless technology and our application of it as a society have improved markedly, making constant and daily communication across the globe possible. The first automobile phone service introduced in 1949 featured bulky equipment and required the placement of a large receiver, the size of a piece of luggage. In order to have a phone conversation, the caller had to push a button while talking and release it in order to hear the person on the other end of the line. In this respect, the phone resembled a two-way radio. What hampered this early technology further was the necessity of an operator routing the call to the desired recipient because calls could not be dialed directly (Belfer 2003). Technology allowing both speakers to simultaneously talk and listen, as well as the capability for a caller to place their own calls instead of going through an operator would not be developed until much later.

Mobile Telephone Service (MTS) introduced the first cell phone service in 1949, but for years afterwards, telephones and cellular devices were bulky devices whose size did not make for portability or convenience (Agar 2013). In the early 1960s, the introduction of Improved Mobile Telephone Service (IMTS) introduced an improvement to the service by eliminating the need to use operators to route calls to phone carriers. In the early 1980s, phones were given full-duplex capability, which allowed callers to simultaneously converse with each other (Agar 2013). In the early stages of IMTS technology, callers often accidentally overheard the conversations of callers nearby as signals were crossed, a problem that was rectified as the technology developed.

As researchers and industry experts have refined cellular technology, cellular devices have not only benefited from decreased size but increased portability, utility and functionality. Cellular devices now offer the opportunity for users to use the Internet, check email, and complete many of the same tasks for which one would normally use a computer. There are, of course, physical limitations on cellular technology. The relatively small size of most cellular devices, coupled with the thermal requirements and limited battery life, mean that the computational capabilities of smart phones are still limited to varying degrees. As cellular technology has advanced over the years, more and more families and individuals in the United States and around the globe are opting to use cell phones rather than traditional landlines (Schram and Carlo 2001).

The development of the cellular phone progressed rather quickly from a device used mainly for voice communication, to a smartphone–that is, actually a fully functioning computer with a multi-purpose capability. Only this year, 2013, the commercial cruise line industry started offering shipboard connectivity for private devices to access the global information grid (GIG) for passengers and crew who are willing to pay for the service while their ships are underway.

Wireless smartphones receive their signals from elevated towers or small hotspots such as in a stadium or commercial building. A cell is defined as the area (several square miles) around a tower from which a signal can be picked up (Farley 2007). A cellphone is a full-duplex device, which means that it utilizes one frequency for speaking functions and a separate frequency for listening capabilities. The division of a city or region into a series of limited cells allows the same frequency to be repeated, so that millions of people can utilize cellular phones simultaneously (Agar 2004).

Cellular phones operate within cells, and have the ability to switch between cells as users travel and move around geographically. Cells give cellphones incredible range, as users are able to drive hundreds or even thousands of miles while maintaining conversations the entire time due to today’s vast global cellular network (Barnes and Meyers 2012). As useful as these networks are, they are largely unavailable to sailors on maritime vessels, who are left with few real-time options for communication and information exchange.

Cellular networks require a large number of base stations in any given region, many of which have hundreds of towers (Farley 2007). The vast number of cellphone users in a region enable per user costs to remain low. Each carrier runs a central office in each region called the Mobile Telephone Switching Office (MTSO) that handles all phone connections to the land-based phone system, and controls all of the base stations.

The reason that traditional cellular technology is so difficult to use while on maritime vessels is a combination of the lack of cell networks and cell stations (Hot spots) available to broadcast signal on steel ships.

Any given smartphone carrier is typically able to receive approximately 832 available frequencies in a city, with every smartphone using two frequencies per call, or what is known as a duplex channel. Each carrier has 395 voice channels and forty-two control channels allowing sixty-six callers to simultaneously talk on their cellular phones without straining the network cell (Cipolla-Ficarra 2011).

Analog cellular systems are considered first-generation mobile technology, or 1G. With digital transmission methods (2G), the number of available channels increases. For example, a “time division multiple access (TDMA)-based digital system can carry triple the amount of calls of an analog system, so that each cell has about 200 channels available (Crockett 2013).

Cellular phones employ low-power transmitters. Many cellular phones have two signal strengths, 0.6 watts, and 3 watts. The base station also transmits signals at very low power. Low-power transmitters have two advantages. The first advantage is that transmitted signals are confined mainly within the cell, allowing two callers to use the same frequencies within the same city. The second advantage is that the power consumption of the cellphone, which is normally battery-operated, is relatively low. Low power eliminates the need for large batteries, therefore making compact, handheld cellular phones a possibility. Health concerns are also a motivator for low power smartphones, especially as the units are now finding their way into the hands of children (Crockett 2013).

The cellular approach necessitates a large number of base stations in any given region, many of which have hundreds of towers. The large number of smartphone users in a region enable per user costs to remain low. Smartphones have special codes associated with them that identify the phone device, the phone's owner, and the service provider (McKinsey Global Institute 2011). The various important smartphone codes in existence are:

1. Electronic Serial Number (ESN) is a unique thirty-two digit number programmed into the phone when it is manufactured;
2. Mobile Identification Number (MIN) is a ten-digit number derived from the device's phone number;
3. System Identification Code (SID) is a unique five-digit number assigned to each carrier by the Federal Communications Commission (FCC) (McKinsey Global Institute 2011).

ESN is a permanent part of the device, while both MIN and SID codes are programmed into the phone at the time of purchase. This is actually a sophisticated computer that monitors all cellular calls, keeps track of the location of all cellular-equipped vehicles traveling within the system, arranges hand-offs between towers, and keeps track of billing information (McKinsey Global Institute 2011). The Mobile Telephone Switching Office (MTSO) contains the switching equipment at the heart of a cellular system. This core system interfaces with the Public Switched Telephone Network (PSTN) through a connection to a Control Office. Carriers operate within the PSTN a network of the world's public circuit-switched telephone networks in much the same way that the Internet is the network of the world's public Internet Protocol (IP)-based packet-switched networks. Originally, a network of fixed-line analogue telephone systems, the PSTN is now digital and includes mobile as well as terrestrial based lines.

When first powered on, smartphones listen for an SID on the control channel, which is a special frequency that the phone and base station uses to communicate call set-up and channel changing. If the device cannot find any control channels to listen to, it recognizes that it is out of range and displays a ‘no service’ message (McKinsey Global Institute 2011). Once an SID is received, the device then compares it to its programmed SID. If the two SIDs match, the device recognizes that it is within its home network. Along with the SID, the phone also transmits a registration request, while the MTSO tracks the device's location in a database, so that it can properly route incoming calls to the intended devices (Crockett 2013).

Once the MTSO receives a call, it attempts to locate the intended device within the database to find the appropriate cell. It then chooses a frequency pair that the device will utilize in that cell to support the call. Next, the MTSO communicates with the device through the control channel to direct which frequencies to use. Once the device receives the communications, the phone may switch to a different supported frequency for the remainder of the linkage time.

As devices move towards the edge of their cells, the base station notes the diminishing strength signal. The base station within the adjacent cells registers the increasing signal strength. The two base stations coordinate with each other through the MTSO, and at some point, the device receives instructions on the control channel to change frequencies to the new cell station (Crockett 2013).

If a user moves from one cell to another, and another service provider covers this new cell, the device is handed off to that service provider. If the SID on the control channel does not match the device's programmed SID, the device recognizes that it is roaming. The MTSO of the roaming cell contacts the MTSO of the home network, which runs the SID through its database in order ensure the validity of the SID. The home network verifies the device as belonging to the local MTSO where its movements are further tracked. The entire process takes only a few seconds to complete. In the case of users traveling internationally, they need to obtain a phone that is compatible with both their home networks and those abroad, as different countries use different cellular access technologies (McKinsey Global Institute 2011).

The 3G technology is intended for use by the current multimedia cellular phones, typically called smartphones, which feature increased bandwidth and high-speed transfer rates to accommodate web-based applications and phone-based audio and video files. 3G comprises several cellular access technologies as follows (McKinsey Global Institute 2011).

1. CDMA2000, which is based on 2-G Code Division Multiple Access;
2. Wideband Code Division Multiple Access-Universal Mobile Telecommunications System (WCDMA-UMTS), which allows users to simultaneously transmit data. UMTS networks support all current second-generation services and numerous new applications and services;
3. Time Division Synchronous Code Division Multiple Access (TD-SCDMA), which TD uses the Time Division Duplex (TDD) mode, that transmits uplink traffic (traffic from the mobile terminal to the base station) and downlink

> traffic (traffic from the base station to the terminal) in the same frame but in different time slots. This means that the uplink and downlink spectrum is assigned flexibly, dependent on the type of information being transmitted. When asymmetrical data such as e-mails and Internet data points are transmitted from the base station, additional frequencies are used for downlink than are used for uplink. A symmetrical split in the uplink and downlink occurs with symmetrical services like telephony (Universal Mobile Telecommunications System 2013).

Digital smartphones utilize the same radio technology as analog phones, but they use it in a different way. Analog systems do not fully process the signal between the phone and the cellular network as they cannot be compressed and manipulated as easily as a true digital signal. Digital phones convert users' voices into binary information of ones and zeros and then proceed to compress them.

Many digital cellular systems rely on frequency-shift keying (FSK) to send data back and forth over AMPS. FSK uses two frequencies, one for ones and the other for zeros, alternating rapidly between the two to send digital information between the cell tower and the phone. Digital cellular phones need to contain a lot of processing power (McKinsey Global Institute 2011).

A cellphone tower is typically a steel pole or lattice structure that rises hundreds of feet into the air. The box houses the radio transmitters and receives the signals that allow the tower to communicate with the phones within its cell. Transmitters and receivers then connect with the tower's antennae through thick cables. The tower along with its cables and equipment are all heavily grounded (McKinsey Global Institute 2011).

Transmitters encode the sound of users' voices onto continuous sine waves, which are simply a type of continuously varying waves radiating out from the antenna and fluctuating evenly through space. Sine waves are measured in terms of frequency. Once the encoded sound has been placed on the sine wave, the transmitter sends the signal to the antenna, which then transmits the signal (Cipolla-Ficarra 2011).

The position of a transmitter inside a phone varies depending on the manufacturer, but it is typically placed in close proximity to the phone's antenna. The radio waves sending out the encoded signal are comprised of electromagnetic radiation propagated by the antenna. The antenna's function in any radio transmitter is to launch the radio waves into space, and in the case of smartphones, the tower's receiver picks up these waves (McKinsey Global Institute 2011).

The term broadband refers to the wide bandwidth characteristics of a transmission medium and its ability to transport multiple signals and traffic types simultaneously. The medium can be coaxial, optical fiber, twisted pair, or wireless (used in hand-held devices). In contrast, baseband describes a communication system in which information is transported across a single channel (Sabri 2013).

Prior to the invention of home broadband, dial-up Internet access was the only means by which users were able to access the Internet and download files such as songs, movies, e-mails, and so forth. It typically took anywhere from fifteen to thirty minutes to download one song (3.5 MB) and over thirty hours to download a movie (typically 710 MB and larger). In 1997, the cable modem was introduced, although the common use of broadband did not experience a significant rise in use until 2001. Having a broadband connection enabled users to download and send files significantly faster when using a dial-up. Properly outfitting naval vessels with effective broadband technology can be difficult, especially since weight concerns can have a huge impact in terms of the ability of a ship to navigate (Konrad 2012).

As with many new technologies, at first most consumers were unable to afford the cost of faster internet service. By 2004, because internet access had become more affordable, most American households considered subscribing to a home broadband service (Thompson 2011).

Smartphones rely heavily on the use of global navigation satellite systems (GNSS). Other uses include Global Positioning Systems (GPS) and its government provided augmentations, which is currently provided free of direct user charges. The majority of smartphones currently in use have the ability to engage these GPS services and access foreign GNSS providers to promote transparency in locating and timing requirements, a function also known as foreign positioning, navigation, and timing (PNT) services. The advent of smartphone technology has brought this space-based situational awareness into the palm of users' hand. Space systems today allow individuals around the world to see one another with more clarity, communicate with certainty, navigate with accuracy, and operate with assurance (Department of Defense and Office of the Director of National Intelligence 2011).

Smartphone devices are wholly dependent on these space-based systems and the localized terrestrial supporting infrastructure for smart phone operations. Together, they create the globally connected cellular network domain. Cellular phones and satellites are also subject to environmental considerations. Factors causing radio frequency disturbances include solar flares, charged particles, cosmic rays, and the Van Allen radiation belts. These and other natural phenomena affect communications, navigational accuracy, performance of on unit sensors, and may even cause electronic failure. Electromagnetic interference (EMI) may be the result of such natural occurring phenomenon. No geographic boundaries exist today for what is commonly called the Global Information Grid (GIG) thus the smartphone may truly be connected to the GIG.

Researchers are constantly striving to develop technological innovations that will make communication at sea easier; one new development may make it possible for ships to access more traditional types of wireless networks. Cell towers stationed on buoys at sea may make it possible to broadcast much more efficient and inexpensive wireless networks (Tateson, Roadknight, and Gonzalez 2004). Both commercial and military sectors are pursuing this technological advancement, hoping that it will make huge inroads in our ability to respond to emergencies.

As situations on commercial cruise liners receive more and more international attention from the media, the push for adopting smartphone technology on ships has become even greater. While passengers were able to make emergency calls during ship emergencies, crewmembers were entirely dependent on the ship's built-in communication systems. Installing cell towers on buoys would not only dramatically cut down on the number of unattended emergencies on commercial ships; it could potentially allow naval forces unparalleled forms of communication (Troutman 2007).

One problem with accessible smartphones on maritime vessels is the fact that frequently, vessels are out of range of traditional terrestrial networks that facilitate cellular communication. Facilitating new types of wireless and cellular networks is a precursor to naval adoption of smartphone technology. For that reason, experts have been working on alternative wireless options that will increase access to Internet as well as smartphone use, dramatically increasing the versatility of technology options open to sailors. One option is a multi-hop network.

Multi-hop networks use a set of relays to convey information, rather than a single hop between a cellular device and home base. Particularly advantageous for maritime vessels, multi-hop networks require less bandwidth than traditional single-hop networks. Conserving bandwidth increases the likelihood of maritime vessels adopting a smartphone/smartphone equivalent policy. Multi-hop networks also make it possible to convey information over longer distances–and when communication is necessary between small naval task forces, that capability could prove useful (Kong and Zhou 2008).

The remainder of this report will explore current capabilities commonly found and used with COTS smartphone operating systems and applications as these capabilities might enhance operations in the Navy. For example, typical application functions that can be found with practically any smartphone on the open market today are point-to-point and point-to-multipoint instant messaging, texting, photo and video capturing, in addition to internet access.

Incorporation of modern mobile computing and smartphones into the armed forces promises to pay off in terms of efficiency and productivity. Leveraging the commercial industry's research and development efforts to satisfy military operational communication's requirements simply would allow leaders to focus more on the message and less on the medium.

Exploring industry-leading COTS cellular capabilities is a sound way to ensure that our troops are equipped with the most capable and accessible tools necessary to accomplish their mission. A requirements-based, cost-effective, and user-friendly smartphone or smartphone equivalent equipped in compliance with the current commercial industry's standards could potentially save the Navy millions of dollars in research and development, as well as procurement costs.

The cost of current communication technology, frequently outdated or in sub-par condition is not just a breakdown in everyday communication between crewmembers. Conventional forms of communication infrastructure—as the fiber optic cables often used to establish a link between ship and shore—are prone to frequent corrosion, necessitating high maintenance costs and often having a pronounced impact on the readiness.

The company requires voice, data, and surveillance fused into a single common operating picture, in order to support centralized and distributed architectures. This includes support to highly mobile forces with on-the-move or over-the-horizon communications for disparate tactical nodes. Achieving this will require increased bandwidth and improved network services. Tactical units must gravitate from push-to-talk radios systems to mobile ad hoc mesh networking (Nicholas and Alderson 2012). Limited bandwidth presents a significant challenge when attempting to transition to smartphones for communication on maritime vessels because networks supported by satellites offer much less bandwidth than would be available in an equivalent network on land. The bandwidth that is available via these networks is also much more expensive than bandwidth available on traditional wireless networks. Since cost is an important factor in terms of budgetary decisions, this may be one reason that the Navy has delayed expanding wireless and cellular coverage on maritime vessels (Ackerman 2012).

Purchasing commercial smartphones and upgrading them to fit the specifications of military needs is substantially cheaper than building new devices from scratch, which would be the primary alternative to purchasing commercial phones (Ackerman 2012). A technological assessment of the Android OS determined that the Android kernel already offers 85percent of the features required to upgrade a smartphone from its commercially available state to a smartphone that is consistent with military security standards.

The U.S. Army has made strides integrating customized smartphones into their repertoire of communication tools, with a plethora of applications available to increase the effectiveness and safety of Army missions on the ground. In 2012, the Army launched a marketplace of its own, offering twelve customized applications for use in military settings (McInnes 2012). Widespread use of smartphones in Army operations has proved to be wildly successful as new and streamlined applications have developed over time, radically changing the way that Army personnel collects, shares, and interprets information (Honegger 2013). Naval forces have been more reluctant to integrate this same technology into their communication strategies because of the difficulty of operating consistent wireless and cellular networks while aboard a maritime vessel.

In 2012, the Navy equipped three ships with wireless networks that allowed sailors and crewmembers to begin using Android phones while onboard ship (Brewin 2012). Status quo policy is to use satellites for communication while at sea. However, it is difficult to procure enough bandwidth for regular internet use or cellular communications due to the cost of supplying bandwidth to ships.

Satellite networks are not the most reliable form of internet connection for maritime ships–physical interference caused by rough seas can make it difficult to maintain a quality internet connection (Ackerman 2012). The telecommunications industry is actively pushing to increase public-private partnerships. Current space systems have the ability to conduct radio-frequency surveys from the Earth's orbit.

The three ships that were outfitted with wireless networks last year received microwave-based wireless wide area networks (WWANs), which offer some unique benefits for maritime operations (Kaiser 2012). Unlike local area networks (LANs), which connect a limited number of computers and/or devices in a limited geographic area, wireless wide area networks are typically larger networks. They also rely on technologies like Long Term Evolution (4G LTE), a process for facilitating wireless communication that uses both GSM/EDGE and UMTS/HSPA technology (Ackerman 2012). Although WWANs are more extensive networks than LANs, they are by no means a suitable option for long-range networks. WWANs typically operate with a range of up to 20 miles–and can serve as a connecting network on the ship or for small naval task forces (Ackerman, 2012). WWANs would likely require modifications to meet military standards for classified and secure communication, especially in light of warnings from industry experts that WWANs may not be secure. These networks will allow sailors and crewmembers to send videos, photos, and real time information, especially in potentially dangerous situations. In the event of a pirate attack or other offensive encounter with enemy forces, these devices would make it possible for sailors to transmit crucial video footage of enemy forces back to their commanders (Ackerman 2012).

“There’s an app for that” is a marketing phrase often thrown around in today’s smartphone dependent world–and it holds true for almost every sector of industry. There are applications created for writers, filmmakers, accountants, cartographers–and in almost every instance, these apps are developed by experts in the field with the insider knowledge that is crucial to make the app both useful and relevant to others in the same industry. Like any other sector of business in the United States, the U.S. Navy has unique needs in terms of smartphone capabilities; the ability to track enemy combatants or report sightings of an enemy submarine is vastly more useful to a crewmember than commercially available consumer applications.

In addition, living and working on a maritime vessel presents certain communication challenges that often make traditional OS’s and smartphone applications unusable for passengers or crewmembers of a maritime vessel. In that sense, developing a smartphone equivalent would be a strategic choice for the military, allowing each crewmember to connect and communicate with their families at home more easily. This type of device would also facilitate sharing information in real time, something that is often lacking when crewmembers are equipped solely with radios. Applications for smartphones or smartphone equivalents aboard a maritime vessel have to confront another challenge before they can truly be useful: the Internet infrastructure on most maritime vessels requires that applications use a relatively low bandwidth and adapt well to the structure of Internet on said vessel (Bruno 2013).

While a particular technology might be a suitable fit for a military need, high cost can be prohibitive when making a purchasing decision. At $15,000 or $20,000 per custom-built device, secure custom smartphones are a significant investment (Magnuson

2012). It is a stark price contrast; commercially purchased smartphones with software upgrades for security could cost less than $500 per device (Hamblen 2011). In this area, smartphones and their accompanying customized applications have at least one obvious benefit; applications can be developed by military employees or contractors who already work in the technology field, making installation on each military smartphone free or very low in cost (Montalbano 2011).

Because applications are so easily created and customized purposes, adapting smartphones on maritime vessels would necessitate a wide range of diverse applications. Some applications would undoubtedly mirror applications already developed for the Army, in that some applications would be designed and developed to support mission-oriented goals. At the same time, there would likely be a huge demand for applications that increase the quality of life of sailors and crew. Applications, for example, that facilitate easier communication between officers, crewmembers, and their families at home, could greatly affect the quality of life for sailors who currently have limited interaction with their families while at sea.

Launched in late 2012, Connect at Sea was developed by MTN Satellite Communications and Wireless Maritime Services (MTN Satellite Communications 2012). MTN Satellite Communications is a privately owned corporation that provides satellite and communication services to both commercial cruise liners and military vessels, while Wireless Maritime Services works specifically on making cell phone service and data plans available while on maritime vessels. The two companies entered into a joint venture to produce an application designed to make communication between sailors and families easier, rather than to fulfill a specific military purpose; Connect at Sea facilitates easy and low-cost communication.

The application allows crewmembers to send and receive both phone calls and text messages without purchasing their own internet service plan; instead, crewmembers can place calls over the ship's wireless network. Current regulations prevent sailors from being able to use their own smartphones or mobile devices on board a U.S. military vessel, leaving them with relatively limited options for communicating with their families at home (Stewart 2012).

While the development of specialized applications is largely dependent on whether or not these military smartphone equivalents are a successful venture for the U.S. military, there are a wide variety of applications that could potentially change the nature of the game for naval operations. Applications for land forces, for example, could help pinpoint the location of friendly forces and potentially cut down on friendly fire incidents. Applications for maritime vessels could help coordinate real-time information crucial to the vessel's mission. The potential for customized Google Maps, for example, could help share routes and navigational hazards submarine sightings, and other relevant information among sailors all in one central location. Some applications like this already exist, though they primarily focus on fulfilling the needs of ground forces. Adoption of smartphones on maritime vessels could, and likely would, spur innovation in terms of applications that make maritime missions easier and more efficient.

Today the US military is networked to individual via handsets, global positioning systems, worldwide satellite coverage, and even very low frequency radio waves used for under-sea communications. The developing sophistication of current military communications programs has allowed the military to move from a naval force that allows ships to communicate via flag or cannon blast while at sea to a force that can send a request, a command, or information in real time to any crewmember on any ship. The ability to share accurate, up to the second information with thousands of people simultaneously has improved the quality of our military operations.

One of the top priorities for naval technology development has to be optimal communication, not only on the ship but also from ship-to-ship. The better communication enabled between ships is, the easier it is for ships to communicate strategy and crucial information in real-time (Bradbury 2013). Lack of proper communication over time has cost thousands of lives, both in commercial and military incidents. Had the crewmembers of the *Titanic* had access to some of the communication tools that are available today, they would have been able to receive more detailed and real-time information about the dangers they were facing–and they would have had an easier time requesting assistance once the ship began to sink.

Access to smartphone technology on maritime vessels could provide two massive benefits for our naval forces: not only could it provide unparalleled levels of communication between sailors and their families, it could increase our military readiness tenfold. In this case, communication advancements have a long history of improving the effectiveness and success of naval operations.

Like the military, commercial sectors have begun to adapt radar technology in order to ensure safe plane navigation and landings. For a safer, more effective, and more cohesive naval force, attempts should be made to procure the most modern, effective and minimally expensive smartphone technology suitable for the needs of the Navy (Beidel, Erwin, and Magnuson 2011).

CHAPTER 3

RESEARCH METHODOLOGY

The purpose of this chapter is to describe the methodological procedures employed to determine whether commercial off-the-shelf (COTS) cellular software and hardware can address the U. S. Navy's individual communication and information distributional requirements at sea. The next chapter will explore many of the key factors associated with COTS cellular software and hardware and the viability of this technology in terms of the needs and requirements of a modern, technologically advanced fleet.

This study was organized as a qualitative descriptive case study. In-depth, open-ended, semi-structured interviews were conducted on a small group of participants who were purposefully selected by the researcher. The participants responded to questions about their experiences using, or their opinions when contemplating the use of, COTS smartphones and related technologies on ships at sea.

Qualitative analysis entails "a process of examining and interpreting data in order to elicit meaning, gain understanding, and develop empirical knowledge" (Corbin and Stauss 2008, 1). A primary value of qualitative studies is their capacity to clarify from a broad, holistic perspective situation that might otherwise seem vague or ambiguous (Eisner 1991). This is a different purpose from quantitative research, the principal goal of which is to establish particular facts derived from data that can be counted and measured. Given these different purposes, reliability may be a misleading way of evaluating qualitative studies (Stenbacka 2001). Trustworthiness may be a more accurate criterion to use as a substitute for reliability in qualitative research (Lincoln and Guba 1985).

Qualitative research needs to specify acceptable procedures for observing (Maxwell 1996).

The current study explores individual qualities that are best discovered through in-person, face-to-face dialogue (Creswell 2009; Pope and Mays 2006; Yin 2009), and therefore qualitative research methods were employed. Qualitative research as defined in this study may be characterized as follows:

> Qualitative research is a situated activity that locates the observer in the world. It consists of a set of interpretive, material practices that make the world visible. These practices transform the world. They turn the world into a series of representations, including field notes, interviews, conversation, photographs, recordings, and memos to the self. At this level, qualitative research involves an interpretative naturalistic approach to the world (Denzin and Lincoln 2000, 3).

Yin asserted that, “a case study is an empirical inquiry that investigates a contemporary phenomenon in depth and within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident” (2009, 18). This study qualifies well for the use of case study analysis as described by Yin, as it proposes to be an analysis, in part, of sailors' real-life experience of using new communication technologies aboard U. S. Naval vessels. Case studies are suitable as a research vehicle in this context as they allow the researcher to explore subjective categories where the key units of analysis are the users of a technology and their perceptions. The researcher may then analyze the phenomenon from the inside perspectives of the users, evaluating the utility of the platform as a function of individual experience.

The protocol followed in the study was based on the standard methods of case study research described by Yin (2009): interviewing as a primary source of data, supplemented by secondary research materials from commercial, government, and academic literature. Two categories of case study the researcher investigated were: (1)

the experience of communications and operational specialists in the U. S. Navy within the context of the current Enterprise Mobility program, and (2) the private operational experience of commercial cruise line personnel.[2] Although military and commercial seagoing experiences are clearly distinct, serving different operational objectives (national defense security and recreational tourism) and criteria (multiple platforms, reliability in extreme seafaring conditions, security from attack, emergency), the study assumes that comparing and contrasting the different standards, systems, expectations and experiences may yield broader comparative insights than would come from analyzing one kind of operation in isolation.

The data collection site for the government side was primarily located at the Office of Naval Intelligence in Suitland Park, MD, where communications and operations leaders and specialists agreed to be interviewed. On the private industry side, the data was primarily collected at the global commercial communications headquarters of the Royal Caribbean International and Celebrity Cruise Lines in Ft. Lauderdale, Florida, where communications and operations specialists agreed to be interviewed. The researcher conducted several interviews in person, supplementing these with followed-up interviews by email and telephone.

The researcher deployed a “purposeful sampling” strategy to select two to four communications and operations specialists to interview about their existing and prospective communications systems, including the use of COTS cellular software and hardware. Purposeful sampling is a technique in which the particular settings, persons,

[2]These included interviews with representatives of Royal Caribbean International and Celebrity Cruise Lines, Norwegian Cruise lines, and one confidential line.

and events are intentionally chosen in order to get information that is not readily available from other sources (Maxwell 1996). Ease of contact and schedule of accessibility of participants was a factor in selecting participants. The following inclusion criteria for participant selection were used:

1. Each participant self-identified as having a deep background of technical knowledge and experience in communications and operations systems in oceangoing vessels and fleets, and an expertise in mobile media technology communications.
2. Each participant self-identified as having decision-making responsibility for recommending and purchasing communication equipment and specifically cellphone or smartphone equipment and supporting infrastructure on behalf of their organization. They were deemed to have a successful history of such purchases through the preparation of written and verbal presentations to their superiors.
3. Each participant self-identified as having had both formal and informal training about communications on ships and maritime operations. Relevant formal training included enrollment in courses in cellphone technology, which were designated by memorandums of attendance and completion with passing grades.
4. Participants self-identified as a being continuously employed as a member of their organization for a minimum of five years.
5. U.S. Navy participants all had a minimum rank of Lieutenant or O-3, on the commissioned officer side and Petty Officer Second Class E-5 on the non-

commissioned or enlisted side of the rank structure. Private organization participants had a position of vice president or above.

6. Each participant was a member of their organizations in good standing with unblemished competence and ethical service and professional records.
7. Each participant spoke and understood the English language and understood basic communication systems engineering concepts.

Participants did not qualify as candidates for the study if they did not fulfill the seven inclusion criteria stated above. Three additional exclusion criteria were:

1. a dishonorable discharged or disqualification from any seagoing organization on competency or ethics charges;
2. a current “on leave” status for disciplinary reasons;
3. inability to articulately answer the questions posed, or otherwise evaluated as unsuitable to be interviewed.

Observation of the code of ethics of practice is vital in any research work. Coleman and Chuan defined ethics as the correct rules of conduct that are necessary for a given research program (Burnham 2013). There are two aspects of the ethics code that were observed for this research: (1) confidentiality of the information related to participants, and (2) measures taken to protect the participants business or trade secrets.

The researcher obtained informed consent from each participant, following guidelines outlined by Plous (2012). Participants read and signed a standard consent form (available upon request). The letter of consent informed the subjects about the objectives, duration, and procedure to be followed in the study. In addition, the letter also informed the participants about the benefits and potential discomforts that participation in the study might cause them, as well as a statement informing them that participation was voluntary and could be discontinued at any time without penalty or recourse.

Semi-structured interviews are helpful for making comparative observations among many interviewees (Bogdan and Biklen 1998). This study included several preselected interview questions that were asked of most participants. Follow-up questions provided the opportunity for participants to offer additional pertinent information. It is the opportunity to ask these follow-up questions that distinguishes semi-structured interview questions from more structured interviews in which there is no option for follow-up.

The researcher periodically asked the participant to confirm and validate the researcher's understanding of important points as a check on potential interviewer bias. Participants in this study responded well to open-ended questions about their experiences and how they formulated strategies. The follow-up questions gave participants the opportunity to reveal their personal thoughts, feelings, and experiences. Understandably, participants generally stopped short of disclosing sensitive business/trade-craft information.

The principal instrument of data collection was the researcher. The researcher asked open-ended questions guided by the research agenda. The interview questions generated desired information about the different aspects of the cellphone, smartphone, or Internet system as a whole for service on ships at sea.

Observation data was compiled from interviews, documents, review notes, field notes, and personal memos.[3] Field notes were written up on location immediately

[3]These memos have been archived in the researcher's personal files.

following interviews. Field notes are an invaluable resource for focusing the observation collection (Bogdan and Biklen 1998). Field notes included interviewer observations on nonverbal behavior, tone of voice, attitude, and level of interest, sincerity, body language, and responsiveness. The field notes also included reference material at times, and at time reference to a source vendor's home web site.

Maxwell suggested that if “your thoughts are recorded in memos, you can code and file them, just as you do your field notes and interview transcripts, and return to them to develop the ideas further” (1996, 12). Self-memos written sometime after completing the field notes record descriptions, summaries, and reflections about the interview responses.

All study responses were evaluated manually. Interview transcripts, field notes, and self-memos were carefully reviewed, analyzed, reduced and organized into responses preliminarily categorized into word frequencies, participant question response frequencies–nodes (clusters of frequencies)–themes (clusters of nodes), and findings (clusters of themes). Nodes reflected recurrent phrases, expressions, and ideas that were common among participant responses. Themes reflected large patterns or clusters of nodes.

The major categories and additional subcategories were numerically coded and compared with observational notes to verify category accuracy and observation position within the categories. In the second coding step, category numbers were collapsed and integrated to create fewer, more generalized categories. Core analysis variables will emerge through observation comparison, which continue until similarities and differences become apparent, and new relationships and categories are created. After this organization and categorization process was completed, three major themes were explored.

The semi-structured interviewing protocol was nearly identical for each participant; this was in order to control internal credibility and reliability in research design, data set, and method of data analysis. Upon interview completion, the participants were all asked to confirm the accuracy of recorded responses to questions.

The researcher was the principal instrument in this qualitative research study. Although validity is not a strong priority in qualitative research claiming limited generalizability, researcher bias is a concern. A preliminary introductory statement was given to each participant prior to the interviews. This statement expressed the researcher's intent and informed participants of their rights. The participants were invited to decline to answer all questions and/or to discontinue the interview at any time without prejudice. Questions were open-ended, inviting participants to elaborate or to provide their personal insights. In addition, some of the questions were structured so that they overlapped one another. Although the questions may have seemed repetitious at times, similar questions were intended to provide a slight variation in emphasis.

The main goal of establishing trust in qualitative research is to impress upon stakeholders in the subject under investigation that they can take the findings seriously (Sinkovics and Alfoldi 2012). Relationship of novel findings to previously reported empirical or theoretical findings is an important element of trustworthiness. Constant comparative analysis was employed to ascertain whether observation-based findings were similar to findings from other studies surveyed in chapter two. Data obtained in this study was deemed trustworthy if it was congruent with known empirical findings.

Triangulation was used to support the trustworthiness of the study. Triangulation is a strategy in qualitative research to prove the validity of a study (Guion, Diehl, and McDonald 2013). According to these researchers, data triangulation involves using a variety of sources or input from participants to improve the validity of the research. The standard questions and follow-ups over the course of the in-depth interviews incorporated triangulation strategies to better understand the different experiences and perspectives of the study participants.

Credibility is the capacity of the research findings to provide a plausible interpretation of the original data derived from the study participants (Carlson 2010). The internal credibility of an interview depends upon the extent to which the interviewer is able to record and analyze participant experiences uncolored by the interviewer's bias or theoretical knowledge of the topic under investigation (Kvale 1996). To bolster internal credibility and avoid distorting participant responses, the interviewer conveyed a supportive, nonjudgmental demeanor throughout the interview process. Participants were asked to clarify interviewer interpretations and to verify the accuracy of their claims in a manner that did not reveal interviewer expectations.

The recorded observations validated by participants were demonstrated by the response context within the larger conversations. According to Kvale (1996, 289), “validation becomes investigation: a continual checking, questioning, and theoretical interpretation of the findings,” and this manner of continuous validation was performed throughout this study.

Attention to internal reliability entails crosschecking participants’ responses in order to clarify apparent inconsistencies, so that the researcher as true to their actual opinions (Kvale 1996) may represent the subjects' experiences. The researcher compared respondents' statements across all of the different sources of documentation: recordings, self-notes and websites. Additionally, the researcher consistently asked the participants further questions to elaborate on the original information they furnished.

Summary

In-depth, semi-structured interviews were conducted with four official representatives of the U.S. Navy of the Communications Enterprise program, and the Royal Caribbean International & Celebrity Cruise Lines and Norwegian Cruise Lines to better understand whether smartphones using COTS cellular software and hardware may address the current U. S. Navy's individual communication and information needs and requirements for ships at sea. The data from these interviews was analyzed manually to identify the categories and emergent themes of the participants' experiences.

CHAPTER 4

CASE STUDY FINDINGS

This chapter discusses four important findings relevant to the adoption of COTS cellphone technology by the United States Navy. These findings result from an analysis of in-depth interviews conducted with USN officers and with representatives of three cruise lines: Royal Caribbean Cruise Lines (RCL), Norwegian Cruise Line (NCL), and one other unnamed private industry cruise line company (UPIC) that requested anonymity. Interviews with USN leaders included Navy Information Dominance Corps (IDC) professionals in maritime intelligence, satellite communications, the internet, wireless mobile and telecommunications, as well a commercial equipment experts. The interview data was supplemented and supported by other published sources, including news reports, corporate press releases, official USN unclassified planning strategy documents, current USN testing reports. These resulting findings were indexed and analyzed in reference to interviewer field notes and self-drafted documents

Creswell (2009) defined the data analysis process in qualitative research as examining multiple sources of data in preference to a single source, requiring the researcher to review all data, make sense of it, and organize it into categories or themes that cut across sources, categories and themes, building from the bottom up (inductive analysis).

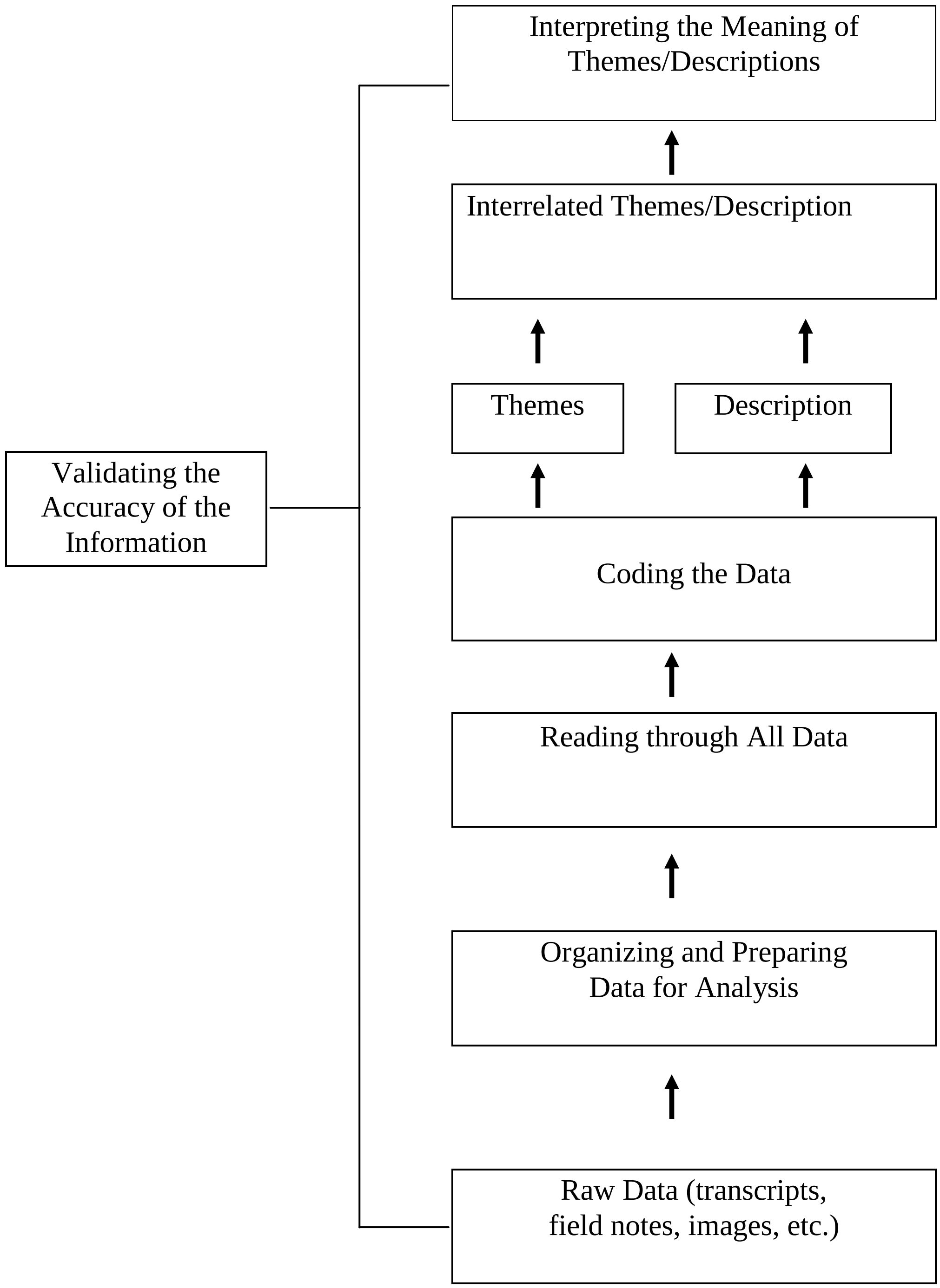

Figure 1. Data Analysis Process

Source: J. W. Creswell, *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches*, 3rd ed (Thousand Oaks, CA: Sage Publications, 2009), loc. 3721.

The analysis of all of these sources of information yielded almost 200 pages of notes. These notes were reviewed numerous times. From these notes response categories were formulated as ‘nodes’ or ‘data points.’ From this collection of nodes and data points, several distinct themes emerged that were then combined to form findings. The notes were then archived in the researcher’s personal files.

Three major findings emerged about the common experiences of the USN, NCL and UPIC. These major findings were supported by ‘themes’—groupings of nodes or categories—that consisted of multiple data sources including the interviews, literature review and personal experience (Creswell 2009). The resulting themes are not comparable to ‘mean’ responses in quantitative studies (Denzin and Lincoln 2000). Rather, unique or idiosyncratic interview responses were considered as possibly reflecting important patterns of thought and behavior in the industries under examination.

Conclusions of the NAVAIR Study

Although a 2013 report from the Office of Naval Intelligence concluded there was a “demonstrated future potential for naval/maritime operations” using COTS technology in a tactical environment (Naval Air Systems Command (NAVAIR) 4GLTE Team 2013, 7), a Naval Operations Sea Trial in a real maritime environment conducted the same year failed to demonstrate validation and reliability of the system.[4] The cellphone 4GLTE service actually “proved to be immature and unreliable for the environment” (NAVAIR 4GLTE Team 2013, 8). Further, according to NAVAIR:

[4]The September 2013 trial was coordinated by NAVAIR with Fleet Forces Command aboard the limited fleet amphibious readiness group (ARG) consisting of the USS Kearsarge, USS San Antonio, UH-IN helicopter and SATCOM.

> User experience was hampered due to registration issues.[5] EMI issues[6] were uncovered due to other ship and aircraft systems. Air-node[7] was not robust in mechanical functioning, software functioning, nor mature TTPs[8] particularly for enterprise shutdown.

The NAVAIR 4GLTE Team explained this unfavorable outcome as "attempting to install a full-functioning system prior to deployment with little solid foundational tech demos occurring prior" (2013, 8). Because of the sea trial, the report added, "performance enhancements have been made to the air-node, radio registration, single tunnel encryption stability, and applications" (NAVAIR 4GLTE Team 2013, 8). The sea trials also showed that:

> The technology [currently available] has most potential for missions conducted in line-of-sight of the ships. The sensor picture provided by the air-node into the command and control areas within the ship provided commanders a picture not normally seen in these circumstances. (NAVAIR 4GLTE Team, 2013, 8)

According to the NAVAIR 4GLTE Team (2013), the "greatest potential" that COTS cellphone service provides is situational awareness for the flag and supplemental plot (SUPPLOT), the landing force operations center (LFOC), boarding teams, and Commander of the Operational Test and Evaluation Force (COTF)[9] for kill-chain analysis[10]. Additionally, other operational applications may include: strait transit;[11] visit,

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[5]Smartphone registration encryption interference

[6]The shipboard environment is a hostile environment for electromechanical communications

[7]Battlefield Airborne Communications Node–potential EMI issue with aircraft survivability equipment

[8]Tactics, techniques and procedures

[9]Also known as COMOPTEVFOR

[10]Target identification, force dispatch to target, decision and order to attack the target, and destruction of the target. Jargon Database, "Kill chain," JargonDatabse.com,

board, search and seizure (VBSS); maritime interdiction operations (MIO); ship's nautical or otherwise photographic interpretation and exploration (SNOOPIE Team); H-60 helicopter (H-60) operations; and landing craft air cushion (LCAC) operations. Moreover, the NAVAIR 4GLTE Team (2013) asserted that, "There is analysis being conducted to see if long term evolution technology (LTE)[12] can be used for International Organization for Standardization commander of the operational test and evaluation force (ISO COTF), Fleet Force Command (FFC), Surface Force Atlantic Fleet kill-chain analysis support (SURFLANT kill-chain analysis support).

Although it is uncertain at this point whether the USN will succeed any time soon in authorizing COTS technology as reliable enough to be integrated into the existing shipboard communication systems, there is no doubt that doing so would fit into the USN's enterprise mobility needs and goals as described in the USN's most recent Enterprise Mobility (2008) report. Enterprise mobility has been defined in this report as:

> the ability to provide Sailors and Marines with the information they require as they move between office, garrison, and battlefield or ad hoc locations . . . that provides the modern warfighter with the 'power to edge' component of net-centric warfare (NCW); indeed, without this capacity NCW would be impossible. (Page 2013)

In general, the report's vision is to:

2010, http://www.jargondatabase.com/Category/Military/Air-Force-Jargon/Kill-Chain (accessed 3 October 2013).

[11] An exercise designed to test a ship's ability to navigate safely, while also dealing with threats that could be encountered transiting straits in hostile waters (Navy News Service Oct 2012).

[12] 4G LTE, is a standard for wireless communication of high-speed data for mobile phones and data terminals.

> Provide robust, secure, and ubiquitous access to the required information through the development of an enterprise mobility capability that incorporates commercially available wireless products and solutions (Page 2013).

More specifically, the USN described this capability as using:

> 'Smart' devices in the field that automatically sense networks, devices, and users and configure themselves to deliver the right [data, video, and voice (note by the researcher)] information to the user through the best network available, and if necessary, connecting to other smart devices within range. (Page 2013)

Moreover, the report enumerated a list of advantages of the adoption of COTS products, suggesting that smartphones or tablets might prove useful for:

1. Assisting in standardizing equipment
2. Providing interoperability across the Department as well as with Joint, civilian mariners/port officials and coalition forces
3. Allowing the DON to take advantage of the research and development of the commercial sector
4. Providing a ready-made, near-global network supporting voice, image and data
5. Preserving the increasingly precious spectrum assigned to the Department through the use of shared, unlicensed frequencies
6. Proving more cost effective than building customized wireless solutions (Page 2013).

These are indeed significant advantages, but they will not be possible until the USN gets past several primary barriers: providing secure communications, navigating the extremely hostile shipboard environment for electronic communications and weapon systems, and delivering messages to users within a useful working range.

Cellular Communications Aboard Commercial Cruise Lines

A second theme of the current study explored the cellular services that have been available and operational since early 2013 on many commercial shipping and cruise lines. Wireless local area network **(**WLAN) infrastructure enables within-ship communications as well as ship-to-shore communications using the full array of COTS commercial communication devices from laptops or smartphones. Ship-to-shore communications, while not as robust as land-based cellular service, provides basic cellular services for most passenger and crew demands, both in port and at sea.

Providing the shipboard infrastructure for cellular service at sea aboard commercial vessels such as those in the RCL, NCL, and UPID fleets is less of a technical challenge than providing such services for the USN—cellphone use on commercial vessels raise fewer concerns over interference by watertight doors and compartments and shipboard electronics. Additionally, security standards are lower in the civilian fleets. Nevertheless, shipboard infrastructure for cellphone service at sea aboard commercial vessels is technically challenging in its own way.

One of the principal challenges stems from the variety of cellphone devices that passengers and crew can carry aboard ship. Other considerations include: (1) the complex variety of voice, data, and video functionality of various cellphones; (2) dropped signals or loss of operability as ships move between rapidly moving communications satellites.

Typically, no shipboard cellphone infrastructure is required for cellphone service close to ports of call and within sight of populated shorelines because the land-based infrastructure will handle most cellphone traffic. Out at sea beyond these lines of sight, however, shipboard infrastructure must take over. The RCL and NCL cruise lines utilize two systems to serve passenger needs and demands: (1) a WLAN system for shipboard communications between passengers and crew provided by Maritime Communications Partner (MCP) named CellAtSea service; and (2) a ship-to-shore system reliant on what is known as a mobile cellular platform using shipboard antennas assembled from various commercial providers by MCP and Harris Corporation. These are located throughout the ship and utilize Comtech modems (Comtech EF Data 2013) to enable shipboard communications with commercial orbiting satellites via ship command systems to relay calls to shore. “One thing that I will say is that for commercial enterprises, it is extremely key to partner with industry experts that can pool technology together into a solution that can be leveraged. Individual providers will change over time, but the integrator is key to make it successful long term” (Martin 2013).

Shipboard communications on RCL use a hybrid wireless/radio communication system known as a WLAN. This system combines a wired local area network (LAN), a wireless area network (WAN), a wireless data network (WPAN), and a wireless wide area network or (WWAN) (Prasad 2004). The LAN enables high-speed data transmission with minimal mobility. The WAN and WWAN enable wireless communications with low data transfer rates. The WPAN enables wireless data transfer within a short range (Prasad 2004). WLANs provide more flexibility that all other systems, enabling wireless connectivity, lower mobility, and higher performance data transfer. WLANs use either radio or infrared technology enabling transmission up to several hundred meters in an open environment. This distance range works fairly well in a commercial shipboard environment.

The frequency band of most WLANs is about 2.4 GHz to 5 GHz. This true list of WLAN channels is the set of legally allowed wireless local area network channels using IEEE 802.11 protocols, mostly sold under the trademark Wi-Fi.

The 802.11 workgroup currently documents use in four distinct frequency ranges: 2.4 GHz, 3.6 GHz, 4.9 GHz, and 5 GHz bands. Each range is divided into a multitude of separate channels. Different countries apply their own regulations to both the allowable channels, allowed users and maximum power levels within these frequency ranges.

2.4 GHz is known as the industrial, scientific, and medical (ISM) band. The advantage of radio waves over wireless digital signals is that they provide connectivity without requiring line-of-sight (LOS) connections. Disadvantages of radio waves include: (1) electromagnetic interference with other equipment using the same frequencies in the same vicinity, and (2) security issues as radio waves passing through walls and bouncing off steel bulkheads. Figure 4-1 illustrates a schematic WLAN wired/wireless network containing a wired and wireless interconnecting system that is a prototype of NCL commercial operations (Prasad 2004, 21).

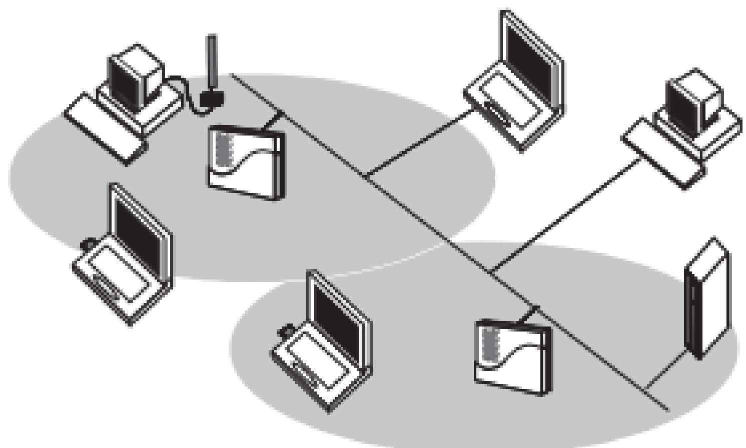

Figure 2. Schematic WLAN

Source: The WLAN is made up of a wireless network interface card, named a station (STA), plus a wireless bridge named an access point (AP). The access point AP connects the wireless network to the wired network. This is also known as an Ethernet LAN. MyFuture.com, “Checklist for Writing a College Essay,” www.myfuture.com (accessed 11 December 2013).

Ship-to-shore cellphone communications aboard RCL enables passengers to call their land-based contacts. Comtech–a privately held company described their system on RCL as follows:

> Comtech EF Data has developed Satellite On the Move (SOTM) technology that provides a method of global satellite coverage maintaining communications between different satellite transponders, beams, satellites and teleports within a Vipersat network. This method allows a shipboard satellite terminal to transition between satellite or hub coverage connections with minimal service interruption. The key components to this technology are hub and remote satellite modems, a stabilized mobile antenna system for tracking geostationary earth orbit satellites or geosynchronous equatorial orbit (GEO) satellites, a central management system maintaining the remote satellite network communication links, and a mobility controller that maintains the connectivity across multiple satellite service areas. (Norwegian Cruise Lines 2013b)

Ship-to-shore communications (voice, text, and other data) at sea are not always available as they depend upon satellite connections that can be intermittent. While mobile service at sea covers international waters, the availability of the service still depends upon a service provider stationed in a particular country. Pricing for these communications are set by the access providers and rate run typically higher than land-based plans. Cellphone service at runs between 25¢ and $1.00/minute, and may charge international roaming charges on top of that base price (Cruise Critic 2013). Fees for internet access at cybercafés on personal laptops cost around 15 to 75¢ per minute, and may be purchased in packages for longer-term use. These communications are considered international rather than domestic and must be purchased separately from domestic carriers.

Many cruise ships offer in-room Wi-Fi wiring, internet cafes, Wi-Fi hotspots in public spaces, and high quality cellphone transmission to serve most passenger needs. On the other hand, internet speeds vary considerably by bandwidth and equipment quality across different locations and different cruise lines. Internet service is currently of lower speeds than land service options (Cruise Critic 2013).

Service at sea is not as robust and reliable as service on land, as it is subject to unpredictable interruption due to weather and international service bandwidth conditions and rules. When ships pull into port in various locations, cellular service changes to reflect local roaming rates and bandwidth availability.

Software and hardware operates behind the scenes to enable these WLAN systems to function more smoothly, seamless, and securely with increasing traffic and greater complexity for data, voice, and video on an increasing number of smart phones and computers. An example of the infrastructure put in place by RCL is the HP Bring Your Own Device (BYOD) system (Hewlett-Packard 2013). The BYOD system enables the user to use his or her own mobile device as long as the handset can be Wi-Fi and/or Bluetooth enabled. Some users have noted problems with this system. For example, Verizon phones operate poorly if at all on sea-based networks. Verizon is aware of the issue and may address it in the near future. For the time being Verizon users are not able to roam while at sea (Cruise Critic 2013).

Developing Smartphone Apps Suitable for the USN

Although recent USN sea trials have not demonstrated validation and reliability of the system as described in Finding 1, the lack of success so far may not diminish the hope or promise that the USN will find a way to succeed in incorporating COTS cellular service compatibility within the USN's existing Hydra onboard communication system. The potential gains in functionality—applications uniquely suited for military operations—as well as cost efficiencies may be just too large to pass up.

Living and working on a maritime vessel presents certain communication challenges that often make traditional operating systems (OS) and smartphone applications unusable for passengers or crews aboard a maritime vessel. In that sense, developing a smartphone equivalent might be a strategic choice for the Navy, allowing each crewmember to connect and communicate with their families at home more easily. This type of device would also facilitate sharing information in real time, something that is often lacking when crewmembers are equipped solely with radios or simply clipboards.

Applications for smartphones or smartphone equivalents aboard a maritime vessel have to confront another challenge before they can truly be useful: the internet infrastructure on most maritime vessels requires that applications use a relatively low bandwidth and adapt well to the LAN structure of that vessel (Crockett 2013).

When outfitting an organization as large as the Navy with new technology or equipment, cost is a significant factor. While a particular technology might be a suitable fit for a military need, high costs can be prohibitive when making a purchasing decision. At $15,000 to $20,000 per custom-built device, secure smartphones can be a significant investment (Magnuson 2012). It is a stark price contrast: commercially purchased smartphones with software upgrades for security could cost less than $400 per device (Hamblen 2012). In this area, smartphones and their accompanying customized applications have at least one obvious benefit.

Because applications are so easily created and customized, adapting smartphones for use on naval vessels would initiate a wave of creative input in developing a wide range of diverse applications. Some applications would undoubtedly mirror applications already developed for the armed forces, in that some applications would be designed and developed to support mission-oriented goals. At the same time, there would likely be a considerable demand for applications that increase the quality of life for sailors. Applications, for example, that facilitate easier communication between sailors, crewmembers, and their families at home could greatly affect the quality of life for sailors who currently have limited interaction with their families while at sea.

While the development of these specialized applications is largely dependent on whether or not these military smartphone equivalents are a successful venture for the Navy, there are a wide variety of applications that could potentially change the nature of military operations. Applications for land forces, for example, could help pinpoint the location of friendly forces and potentially cut down on “friendly fire” incidents. Applications for naval vessels could help coordinate real-time information crucial to the vessel’s mission. Some applications developed for military purposes already exist, although most of these primarily focus on fulfilling the needs of ground forces. Adoption of smartphones on naval vessels could, and likely would, spur innovation in terms of applications that make maritime missions easier, safer, and more efficient.

Launched in late 2012, Connect-at-Sea™ was developed by MTN Satellite Communications and Wireless Maritime Services. MTN Satellite Communications is a privately owned corporation that provides satellite and communication services to both commercial cruise liners and military vessels, while Wireless Maritime Services works specifically on making cell phone service and data plans available while on commercial maritime vessels. The two companies entered into a joint venture to produce the application. Designed to make communication between crewmembers and their families easier, rather than to fulfill a specific military purpose, Connect-at-Sea™ facilitates easy and low-cost communication. The application allows crewmembers to send and receive both phone calls and text messages without purchasing their own Internet service plan; instead, those aboard the ship can place calls over the ship’s wireless network. Present

USN regulations prevent crewmembers from using their own smartphones or mobile devices on board a U.S. military vessel while underway, leaving service members with limited options for communicating with their families at home.

Some cellphone users have expressed concern over the possible health risks related to cellphone use. Use of these devices in confided steel quarters while on a ship at sea may present increased risk. Smartphones will increase their power output to try to reach a cellular tower from a typical operating power of 0.5 watts to up to 3.5 watts when in spaces such as an elevator, a concrete-and-steel parking garage, or a steel ship. Cellular phones are typically placed against the user’s head and ear in a telephone conversation. Some users fear that the proximity of the device to the body presents a risk of electromagnetic radiation absorption by human tissue. Given the close proximity of the phone to the head, it is not hard to imagine how the radiation might harm the user. What is being publicly debated online and in the news media is what are the potential long-term effects, if any, of radiation exposure from cellphone use.

There are two types of electromagnetic radiation: ionizing radiation and non-ionizing radiation. Ionizing radiation, found in gamma rays and X-rays, contains enough electromagnetic energy to strip atoms and molecules from living tissue and alter chemical reactions in the body. Humans typically protect their bodies with lead vests when they have to be exposed to this type of radiation. In contrast to this, the non-ionizing radiation found in visible light, microwave radiation and radio frequency energy is considered much safer. This form of radiation does emit some heat, but typically not enough to inflict long-term damage to human tissue (Schram and Carlo 2001, 84).

A cellphone's Specific Absorption Rate (SAR) is a measure of the amount of radio frequency (RF) energy absorbed by the body when using the handset. All cellphones emit RF energy and the SAR varies by model. For a cellular phone to receive Federal Communications Commission (FCC) certification and be sold in the North America, its maximum SAR level must be 1.6 watts per kilogram (Federal Communications Commission Encyclopedia 2013). In Europe, the level is capped at 2 watts per kilogram. The SAR is the measurement used to determine how much energy is absorbed in a specific about of space.

Radiation can cause damage to human tissue if the exposure to RF radiation crosses a certain threshold. RF radiation has the ability to heat human tissue in much the same way as a microwave ovens heat food. Damage to tissue can be caused by exposure to RF radiation when an emitter becomes hot enough to burn skin. Few consumers express special concern over injuries resulting from shattered glass or exploding batteries. The concern, rather, is over the long-term effects of exposure to low levels of RF radiation with prolonged daily use.

Although typical cellphone use may not immediately cause damage to tissue, many consumers are still unsure about whether prolonged exposure could create health problems. This continues to be a cause for alarm in the news media today as the number of cellphone users continues to increase. Some of the diseases and symptoms that are suspected of being potentially linked to cellphone radiation are cancer, brain tumors, Alzheimer's, Parkinson's, fatigue and headaches. Are such fears justified, possible signs of hypochondria, or does the truth lie somewhere in between?

The cause for concern is the possibility that the negative effects of microwave radiation might accumulate over time. In order to work, cellular phones have to send and receive signals from a base station, connecting with all other cellular phones in an area to form a web of information carrying radio waves. The Federal Telecommunications Act of 1996 essentially prevents local authorities from considering health concerns in deciding where towers are to be placed. The FCC and the FDA, which regulate cellphone carriers, claim that because the cellphone produces no heat, it is safe for all to use. Rumors have spread over the internet of skin cancer, especially at the favored ear for cell communication, due to “DNA double strand breaks” from the use of smartphones.

Cellphones contain hazardous materials, leading the U.S. Environmental Protection Agency (EPA) to regulate their proper disposal, noting that there is a large volume of cellular phones retired each year, likely up to 150 million per year. In their circuitry, batteries, and liquid crystal displays, cellular phones can contain toxins such as arsenic, nickel, columbite-tantalite (coltan), beryllium, cadmium, copper, and lead. Some of the metals may be recycled. Their plastic casings are also treated with brominated flame-retardants (U.S. Environmental Protection Agency 2013). The EPA has an entire website containing information on disposal techniques and upgrading recommendations, however they currently have left out the potentially adverse health effects to humans because of cellphone use. Currently, the FDA tests microwave ovens for safety, but does not conduct any test on cellular phones.

Although most users disregard possible side effects of cellphone use, cellphone manufacturers are beginning to issue disclaimers to preempt the threat of possible lawsuits. As of 2010, the Motorola V195 model included a warning to keep the phone

one inch from the user’s body; the BlackBerry 8300 also has a warning of 0.98 of an inch; the Nokia 1100, one fourth of an inch; and the iPhone five-eighths of an inch. The new Verizon Droid Eris cell phone contains a ‘Product Safety and Warranty Information’ booklet that advises users “that no part of the human body [is to] be allowed to come too close to the antenna during operation of the equipment” (Verizon 2013, 11).

A customer query about this was referred to an online appendix, which explained on page 219, “To comply with RF exposure requirements, a minimum separation distance of 1.5 cm must be maintained between the user’s body and the handset, including the antenna” (Sciutto 2011). Similarly, the iPhone 4 user manual includes a warning about exposure to radio frequency energy that states:

> For optimal mobile device performance and to be sure that human exposure to RF energy does not exceed the FCC, IC, and European Union guidelines always follow these instructions and precautions: When on a call using the built-in audio receiver in iPhone, hold iPhone with the dock connector pointed down toward your shoulder to increase separation from the antenna. When using iPhone near your body for voice calls or for wireless data transmission over a cellular network, keep iPhone at least 15 mm (5/8 inch) away from the body, and only use carrying cases, belt clips, or holders that do not have metal parts and that maintain at least 15 mm (5/8") separation between iPhone and the body. (Apple 2013, 5)

The phrase “heart stopping phone calls” was coined in the early 1990’s. Increasingly, reports of users' pacemakers being stopped by cellular phones surfaced (U.S. Food and Drug Administration 2013b). The FDA kept track of such reports and noted that heart defibrillators were also reported to be failing after cellular phones were used in close proximity. None of the cases featured reports of cancer, and all involved electronic interference. In Italy, this prompted researchers to test digital cellular phones in a laboratory and in patients with pacemakers. When the phones operated in close proximity to the pacemakers, about four inches, interference of some type was found in half the instances (Schram and Carlo 2001, 84).

With the rapid proliferation of social networking websites such as Facebook, Linked In, Twitter, MySpace, and Bebo, people are eager to stay connected with their friends and family and are open to sharing personal information with others. This led researchers to explore Opportunistic Localization System (OLS) for smartphones and related devices and gadgets. OLS has the ability to bridge the gap between outdoor and indoor localization via Wi-Fi, GPS and other networking systems. This allows mobile devices to locate others with whom they share common interests almost anywhere in the world. Currently, manufactured mobile devices also have inertial sensors built in (mostly accelerometers or compasses) that can be used as extra localization information using the pedestrian dead reckoning (PDR) principle, which is used to estimate distance.

Individuals' use cellular phones everywhere, even when doing so poses a danger, such as driving. Multiple states have passed laws against the use of cellular phones while operating a vehicle. Some studies have shown, driving while on the phone or texting is more dangerous than driving under the influence of alcohol (Barkoviak 2013). Constant cellphone use may be creating behavioral changes in the user and influencing young adults in a particularity negative way.

The FCC and the FDA both report, based on a large body of research, that cellphone use is safe for consumers. For example, a massive 13 year cohort study in Denmark published in the Journal of the National Cancer Institute followed the cancer histories of 420,000 cellphone users over thirteen years looking for increased incidences of leukemia, brain cancer, nervous system cancers and salivary gland cancer, and leukemia. The report concluded:

> Risk for these cancers . . . did not vary by duration of cellular telephone use, time since first subscription, age at first subscription, or type of cellular telephone (analogue or digital). Analysis of brain and nervous system tumors showed no statistically significant [standardized incidence ratios] for any subtype or anatomic location. The results of this investigation . . . do not support the hypothesis of an association between use of these telephones and tumors of the brain or salivary gland, leukemia, or other cancers (Johansen, Boice, McLaughlin, and Olsen 2000).

In light of such studies, the U.S. Food and Drug Administration (FDA) have concluded, “the available scientific evidence does not demonstrate any adverse health effects associated with the use of cellular phones” (U.S. Food and Drug Administration 2013).

In spite of a wealth of statistical data to contraindicate cancer risks resulting from cellphone radiation, public fears and rumors persist. Those who continue to use the devices in the face of possible health risks may consider the immediate advantages to outweigh the remote and merely potential costs. It seems clear that the use of cellular phones is now commonly considered a voluntary risk. A voluntary risk is much more acceptable to users than an imposed risk. Risks that individuals can take steps to control are more acceptable than those they feel are beyond their control. These outrage factors are not distortions in the public’s perception of risk. They help to explain why the public fears pollutants in the air and water more than they do geological radiation or micro radiation waves.

The problem is that many risk experts resist the use of the public’s ‘irrational fear’ in their risk management. A problem exists in the perception of risk, because the experts and laypersons views differ. The experts usually base their assessment on mortality rates, while the layperson’s fears are based on the aforementioned ‘outrage’ factors. One additional example is the ongoing concern for the risks involved with cigarette smoke. Another effort must be made to decrease the public’s concern with low to modest hazards, that is, risk managers must diminish ‘outrage’ in these areas. In addition, individuals must be treated fairly and honestly so that trust is built between exposed communities and the risk managers and responsible parties (Theodore 2012, 311).

While it cannot be denied that cellular phones and the associated technology has propelled every single industry in the world and represent a clear advance in communications technology, there are risks that need to be addressed. Every year, insurance companies pay thousands of dollars to cover accidents that resulted due to the careless use of cellular phones and other hand held technology. Research has proven that using a cell phone during driving results in much slower reaction times than driving under the influence. When drivers kill another person due to texting or cellphone use, this has the same effects as when something similar results from the combination of driving and alcohol and drug use. These events cannot be reversed, but even though they are serious, not enough drivers are acknowledging the risks. Law enforcement officials need to work with drivers in order to pass laws that will save and protect lives. The truth is that society has become so accustomed to its dealings being constantly on the go and instantly accessible that humans are willing to risk their lives and those of others in an attempt to do what they seemingly feel obliged to.

Changes can be implemented not only with laws, but also with new cellphone designs. Cellular phones that operate much easier when they are in speaker mode would facilitate users being more willing to use this function. This would also help alleviate many concerns regarding adverse health effects because of cellphone use.

Technology has come a long way since the beginning of the 20th century, and it can certainly go much farther in a bid to improve itself, be more functional, and help protect human life. As we learn of possible health risks, human creativity should be able to meet these challenges with technology to counter the health risks. Appendix A contains recommendations for minimizing potential health risks while using cellphones.

Three major findings emerged from this study. The first finding was that although there was a “demonstrated future potential for naval/maritime operations” (NAVAIR 4GLTE Team 2013, 7), using COTS technology in a tactical environment, recent live Naval Operations Sea Trials (COMTUEX) in a real maritime environment, did not demonstrate validation and reliability of the system. The cellphone 4GLTE service actually “proved to be immature and unreliable for the environment” (NAVAIR 4GLTE Team 2013, 8).

The second finding was that cellular service is currently available and operational on several commercial shipping and passenger cruise lines. It appears the RCL technology staff is the most advanced at this time due to their ability to swiftly switch contractors of overhead bandwidth providers and install new ship antennas as soon as they are receivers are available. WLAN infrastructure enables within-ship communications as well as ship-to-shore communications using the full array of COTS commercial communication devices from laptops (Or other motherboard) to smart phones. Ship-to-shore communications, while not as robust as shore based cellular service, provides basic (although not the most advanced and sophisticated) cellular services for basic passenger and crew demands and needs in port and while underway at sea.

The third finding was that although recent USN sea trials have not demonstrated validation and reliability of the system (as described in the first finding), the lack of success so far may not diminish the hope or promise that the USN will find a way to succeed in incorporating COTS cellular service compatibility within the USN's existing HYDRA onboard communication system. The potential gains in functionality—applications uniquely suited for military operations—as well as cost efficiencies may be just too large to pass up.

These findings illustrate the direction and challenges facing the USN in achieving its enterprise mobility goals. The key to success is flexibility and rapid adaptability to evolving technology in this field—an issue the USN has not yet been able to master. This is the key benefit for COTS technology today, an ever evolving and advancing space. Current terrestrial cellular network providers were not designed for continuous data usage as we are seeing today. This fact can help better prepare and build future requirements for the next generation of connectivity pipelines, ultimately designed for continues demand by wireless users on the move, in the air and on the sea.

RCL is still addressing the rigorous requirements required for this equipment at sea. Ships require the most advanced technology available, only second to space travel. Wireless communications support collaboration, safety of the maritime industry and data exchange required in the process of maintaining and overhauling legacy communications gear on ships.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

The purpose of this study was to explore the viability of using commercial off-the-shelf (COTS) cellular smartphones running on commercially available software platforms to address the communications needs of large deck U.S. Navy ships deployed at sea. The study found that the COTS systems tested in a recent USN sea trial failed to receive authorization for deployment in active duty service. Nevertheless, the study recommends the USN should continue to seek ways to incorporate COTS smartphones in a tactical environment in order to benefit from potential advantages in functionality and cost.

The adoption of COTS wireless systems by large-scale retail complexes, theme parks, airports, and megamalls provides a model in private industry that suggests the potential benefits for widespread adoption by the USN. Dozens of new COTS mobile computing devices support hundreds of thousands of new applications, continually being developed and updated, and the flexibility and multi-functionality of existing smartphone platforms readily lend themselves to retooling and development for military purposes.

In the broadest terms, the technology provides the potential for greatly elevating tactical performance of the entire USN fleet, facilitating rapid and varied communications options among individual sailors. This study found that the technology is already in use aboard commercial vessels carrying 3,500 or more passengers within large, integrated fleet systems. The cruise line models present an example of how shipboard infrastructure can accommodate cellular smartphone service at sea, demonstrating that COTS cellular service is feasible at sea within large ships.

Principal impediments to incorporating COTS communications into the USN fleet include the more the more rigorous criteria demanded by the military for secure, reliable, and flexible service. Concerns about stable coverage over vast regions of the world's oceans also present a limiting concern for the USN’s large, multi-capability fleet operating above and below the oceans’ surface in international waters.

Where cellular technology is headed is indeterminate, but the possibilities are intriguing to contemplate. The first smartphone–the Apple iPhone that was hailed as a breakthrough as the first multi-functional, hand held, mobile touchscreen computer–was released in 2007, just six years ago. Much has happened in those six years as Apple developed for the mobile computing market the first touch screen tablet, the iPad, in 2011 and the scaled down iPad Mini in 2012–both of which use 3G cellular technology as well as Wi-Fi connectivity. Additionally in 2013, Apple released its newest edition of the iPhone 5 with groundbreaking fingerprint technology that elevates the level of security, effectively lowering one the principal concerns by the USN and many others.

Over the past six years, the smartphone and related tablet computers using cellular technology have become so popular that these mobile devices have undermined the market share and survival of conventional cellphones lacking touch screens and a viable platform for the booming app market (such as BlackBerry) and seriously disrupted the demand for desktop, laptop, and notebook computers (Bajarin 2013). What is remarkable is that we are very much at the beginning of this new mobile communication era. The fact that people are even deliberating the use of smartphones as a tool for sailors on naval vessels, and that cruise lines have already adopted the technology for seagoing passengers on large commercial vessels is an indicator of how functional and highly esteemed this new technology has become. These vessels contain large, groups of 3,500 or more people, separated from their families, who are traveling in remote, environmentally vulnerable conditions on the open high seas–in areas subject to pirates and terrorists, violent storms, other extreme weather conditions, giant rogue sea waves, icebergs, treacherous shorelines with hidden reefs and shoals, limited insurance coverage, electronic hacking, lack of legal protection, law enforcement and limited medical and rescue accessibility.

On commercial cruise ships, passengers enjoying the pleasant ambiance may have a false sense of security about the potential risks they actually face. Enhanced communications made possible by smartphones have changed everything for these vacationers, enabling vital communications and information transfer where limited options for communication were previously available.

The smartphone has been projected to account for 70 percent of all global media distribution by the year 2015–an unprecedented rate of growth for a brand new technology (Rossignal 2013). In the past, our challenge was accessing information; these days, our challenge is parsing, screening, and managing the onslaught of information. To make sense of it, we must wade through a mass of material flowing at us every day, selecting only what is relevant and discarding what is not. In this seek-sort-and-share environment, the smartphone has become the most accessible tool for distribution, dissemination, and sharing of information (Madrigal 2013).

While the web has enabled more entrepreneurs and businesses to flourish mainly through disintermediation (getting rid of the intermediaries) and through open access to information, its overall impact soon may seem very small compared to the information processing and distribution power and speed of the smartphone. Emphasizing this point, the venture capitalist Marc Andreessen stated, "The smartphone revolution is UNDER hyped" (Andreesen 2013). Moreover, the revolution is in its very early stages. These handheld powerful computers (smartphones, phablets, and tablets) have disrupted everything as revolutions are wont to do, but on balance, it may be for the better–far more creative than destructive (Pink 2013).

Due to a current shortage of personnel, the Navy is exploring the possibility of improving personnel efficiency by applying wireless LAN technology to a variety of routine operations. Three promising areas have be analyzed in this study: (1) personal COTS cellular communications systems that may be put to use at sea by individual naval seamen; (2) broader COTS cellular communications applications that are currently being used on commercial cruise lines by civilians and that may have naval applications; (3) and specific COTS cellular communications technologies and standards that are possible to be used in WLAN but presently are not yet fully deployed, particularly the IEEE 802.11a standard and the WLAN configurations with Cisco routers that may be used in a deployment aboard ships.

The post-load software applications in its App Store are mainly proprietary. Mobile applications for the iPhone do come from multiple sources, but once procured by Apple, the applications are compiled and therefore only usable "as is." A compiled code makes it nearly impossible to decipher the original coding. This means if users have a unique requirement for which there are no applications, users can either create the application required to service the particular requirement, if they know how to write code as an Apple app or solicit for an application to be developed for them that will satisfy their particular need. Alternatively, they could just wait until an application that does satisfy their requirement is written, approved, and made available for download from the App Store by an application developer.

Any of these options, however, may entail lag times that could potentially be problematic for a host of military end uses. When a unique requirement comes up and a software solution can address it, the military would want immediate access to it. Furthermore, with so many applications being created and added to the App Store on a regular basis, it is plausible that there are applications that could, with minor modifications, appropriately address a number of unique USN requirements for sailors performing their duties at sea.

The selection and quotes of particular hardware and software discussed in the recommendations section of this study represent only the views of the researcher and do not constitute an official endorsement of the use of particular application, hardware, or platform. A fundamental justification for the military use of COTS cellular technology is to leverage substantial cost and time savings that are possible by using an available integrated ecosystem of hardware and software to fulfill requirements. A drawback of using the Apple iOS system is that the system is fundamentally proprietary, meaning there is limited flexibility to adjust the hardware and software to modify its functionality. Systems running Windows Phone 8, BlackBerry and Bada platforms, in contrast, permit more open-source coding for their mobile applications. A platform that is vastly more open-source than closed- source may serve the military needs better in the end.

Based on the Navy‘s unique requirements, the uncertain nature of the environments that the fleet operates in, and the versatility offered by the manufacturer's software operating system (OS), the researcher recommends Android as the platform the Navy should look to for further consideration. Selecting Google's Android OS software would enable the USN to remain hardware agnostic and enable a launch pad that may provide the USN access with a greater number of available applications that can be reprogrammed as necessary to address military-unique requirements. Incorporating either a tailored security-enabled device or an external add-on security feature to a base model device, such as a security sleeve, and employing it on a network such as one of the earlier proposed notional Department of Defense (DOD) cellular networks may be an approach to deliver COTS technology to the desired tactical edge for troops engaged in combat.

Additional sea trials for the USN are recommended through the platforms of the US Navy's SeaLift Command. This organization would provide an ideal base of operations for follow-up sea trials because of its diverse fleet consisting of many types of shipping vessels, a global presence that would enable testing in a variety of challenging environments, and the existence of vessels that have fewer water tight doors and less advanced electronic communications and defense equipment that are currently causing electromagnetic spectrum fratricide. This command also has fewer crewmembers afloat per vessel, and fewer restrictions and DOD requirements for the use of Internet at sea, enabling a closer fit of the COTS cellular equipment. Additional information about the SeaLift Command may be obtained from http://www.msc.navy.mil/mission/.

Position Location Information (PLI) may be a method used by the navy in its operations in the future as this feature develops. PLI is a system that provides the capability to accurately locate a device if it is lost. This is only possible if the device being searched for is equipped to generate a locating signal that is strong enough to be detected within a particular cellular coverage area (Krishnamurthy, Tipper, and Joshi 2013). The PLI system works differently from the Global Positioning System (GPS) that uses a satellite constellation system to locate devices, addresses, or specific coordinates on the surface of the Earth.

The USN is investigating the pervasive computing systems being developed for large-scale retail complexes and large highly populated indoor environments, such as theme parks, airports, and megamalls. One COTS application that may fulfill USN future requirements at sea is a system known as the opportunistic localization system (OLS) that enables localization services that work seamlessly in heterogeneous environments such as both indoor and outdoor environments, as distinctive from systems that are outdoor-based-only. Apple Corporation offers a service to clients know as iBeacon that offers very similar capabilities. Students are eager to locate their peers on a campus or in buildings and stay connected with them, OLS makes that simple. The core technology for OLS is an opportunistic location system for smartphone devices that grasps at any location related information readily available in the mobile phone instead of requiring a fixed dedicated infrastructure to be installed in the user's environment. The latest version of OLS reduces the system ownership cost by adopting a patented self-calibration mechanism minimizing the system installation and maintenance cost. This system may be a good candidate to be included in upcoming sea trials. Information about this system may be obtained at http://conferences.sigcomm.org/sigcomm/2009/workshops/mobiheld/papers/p79.pdf.

It has been very challenging to access and obtain extensive and detailed cellular use information from potential private industry cruise ship and oil industry sources. The interviews conducted in this study frequently resulted in helpful referrals to technical manuals or web-links describing some products that were being used. Obtaining candid descriptions of comprehensive systems and troubles, or company criteria and objectives on the other hand were difficult to come by. One cruise company requested that the name of the company not be disclosed, indicating that upper management may not approve the disclosure or competitive pressures were restricting information sharing.

The scope and time available for this study did not provide the opportunity for this researcher to investigate many services that have been coming on-line in the private industry.

Combat is the ultimate proving ground for any weapon system, transport vehicle, or communication asset designed to assist the member in accomplishing any given mission. Missions at sea can be harsh and the operational equipment and tools selected may need to be fortified to withstand the physically demanding, climatically variable, and frequently extreme wet, humid, vibration heavy and salt air environment.

As mobile technology evolves, the Navy must be in a position to move from vendor to vendor overnight despite the recommendation offered herein. Lengthy contracting negotiations and overly binding commitments may delay and confound the deployment of technology to fulfill mission requirements. In addition, the technology industry is progressing at such a rapid pace that it behooves the USN not to over-commit with their contracts today to systems that may quickly become obsolete tomorrow. Keeping options open, thus maximizing flexibility and speed of adoption are key requirements. Moreover, maintaining a close working relationship with industry experts may be the most prudent way ahead to keep up with the rapid pace of change and openness to unimagined opportunities–much as we are just now starting to witness in Americas Space program, as the focus shifts from government to private initiatives.

The U.S. Navy's SeaLift Command may be the place to start the experimentation, testing, and deployment of tools for shipboard internet and cellular smartphone service. In the not too distant future, it may even be possible that the ocean's seawater itself will be used to transmit GIG signals over extended ranges and at much higher speeds with large bandwidth from the sea floor to the surface and subsurface vessels alike. The USN is just starting to use saltwater antennas with controlled water jets using the salt water under vessels as the conductive receiver and transmitter.

Finally, much more information sharing is required. According to three separate cruise line information offices, this researcher was the first Naval Officer to request information about their COTS BYOD cellular communications operations, providing internet and voice mobile connectivity to guests while at sea. The energy industry is actually the largest wireless user in the off coast connectivity market (Rystrom 2013). If the largest industrial enterprises in the world such as Exxon-Mobil, Chevron, Conoco-Phillips, Slumberger, BP, Statoil and others are putting wireless COTS cellular systems to work at sea in some of the harshest and most unforgiving climatic conditions, why shouldn't the USN?

We have seen gadgets that can measure heart rates, how many calories we are burning or how many steps one takes. Then there are devices that go even further such as Google Glass, which displays text messages and news feeds right up near the users eyes. When referring to a smartphone, we must also consider all kinds of other wearable connected gadgets to improve productivity. In offices all over the world, workers are getting smart badges that tell how engaged or stressed they are during meetings, while warehouse crews are being supplied with talking glasses that warn them if they're about to fill an order incorrectly or crash their forklift. Walt Disney World Resort is testing wristbands equipped with RFID transmitters at its Orlando, Florida. Guests can use the RF bands as a hotel-room key, parking tickets and charge cards by touching an RFID reader. The bands also connect to Disney's vacation-planning system, where guests are able to make reservations for meals, reserve attractions in advance and share vacation photos, among other things (Wilson 2013). Companies as well government agencies such as the Navy will continue equipping employees with wearable useful unintrusive gadgets to enhance their productivity, safety, and security.

> I'm a great believer that any tool that enhances communication has profound effects in terms of how people can learn from each other, and how they can achieve the kind of freedoms that they're interested in.
>
> ―Bill Gates, Microsoft Website

APPENDIX A

CELLPHONE SAFETY RECOMMENDATIONS

If individuals choose to use cellular smartphones, they can minimize their exposure to radio waves by:

1. Keeping their calls short and to a minimum
2. Considering relative broadcast power (SAR values) when purchasing a unit
3. Using the speaker setting and keeping the handset away from the head and body
4. Using a low power wireless headphone with a low power Bluetooth emitter
5. Using a wired headset unit
6. Considering the use of airplane mode, when in non-connectivity use
7. Placing the phone away from the body as much as possible
8. Keeping the unit powered off when keeping it next to the waist
9. Only using the unit when signal strength is good (near a hotspot)
10. Avoiding using the device in a closed-in environment, such as an elevator
11. Avoiding using the device in a very small compartment, such as a ships DeCon cell
12. Texting rather than calling
13. Advising pregnant women to keep cellular phones away from their abdomens
14. Protecting babies and youth from cellphone exposure
15. Keeping the cellphone off when in your pocket and not required
16. Using a landline or ship bases desk phone when possible
17. Avoiding texting and/or speaking on a cell phone when driving

18. Avoiding texting and/or speaking on smartphone when on flight deck operations
19. Keeping all Bluetooth and Wi-Fi settings ‘off’ when not in use
20. Reading all user manuals and the FCC web site for updates on health risks from cellular phones at www.fcc.gov/cgb/cellular.html.

APPENDIX B

CONSENT FOR PARTICIPATION IN RESEARCH INTERVIEW

Study Title:

Principal Investigator:

Faculty Supervisor:

Please read the information contained in this form carefully and fill in the blank spaces to provide your consent for participation in this research. To take part in the research you must be 18 years of age and above. Please be informed that your participation is voluntary, and you have the right to withdraw you consent in the course of the research without subsequent prejudice.

Description of the Study

This is a research in communications and operations technology and specifically in cellphone infrastructure technology aboard government and commercial shipping fleets, in which you will be requested to answer questions in an interview format. The interviews will last approximately 20 to 40 minutes and notes will be taken during the interview. An audiotape will not be used for this interview**.** Later follow-up interviews, emails, phone calls and text messages may supplement the principal interview.

Purpose of the Study

This study aims at determining whether smart phones using commercial off-the-shelf (COTS) cellular software and hardware can address the U. S. Navy's individual communication and information needs and requirements at sea, uncovering and analyzing many of the key factors that enter in to the use of COTS cellular software and hardware.

Possible Risks

During the research process, you may feel that your performance regarding the treatment and recovery process is poor. However, there are no negative responses in this research. Please be informed that some participants may perform better that others, but you honest response to questions is highly appreciated.

Possible Benefits

Your participation in this research will give you an opportunity to contribute to the reform in current Navy large deck individual communications, which is currently an intriguing issue in the Navy.

Confidentiality

The information giving your identity will be removed from the questions once the participation is complete. Only the researcher will maintain your raw answers in his personal files. The interview results are to be kept in a secure place, to avoid access by unauthorized persons.

Opportunity to Question and be Informed

You have the right to ask any question regarding your participation and the research process. Kindly direct your questions to Principal Investigator: LCDR Frank Kostenko.
Cell Phone: 818-262-9440, e-mail: Fkostenko@yahoo.com or Frank.Kostenko@navy.mil.

Opportunity to Withdraw

You have the right to withdraw you consent of participation in this research at no penalty.

Date:

Signature of Participant:

APPENDIX C

NETWORKS AT SEA INTERVIEW QUESTIONS

1. What hardware do you use for the terrestrial base station?
2. What satellite service do you use for your global footprint of the seas?
3. What ship receiving equipment do you currently use on your ships?
4. How do you 'distribute' the hot spots on ship? Routers and software?
5. What hardware and software do you use on the ships for the BYUD applications?
6. Does any particular COTS smart phone today work better at sea? If so why?
7. Weather Navy or a commercial SATCOM requirement is being explored, this are the researchers parting questions to use as the project manager moves ahead with the requirement for smartphones and internet at sea. It is important to always evaluate two or three SATCOM providers and get solid references. Do not be sold based on time constraints. Additionally, be sure you are comparing apples to apples and not signing an agreement based solely on prices and promises. Most networks can go up quickly and use similar equipment, so always do your homework first.
8. Trialing a service is the best way forward. Do not just trial the bandwidth level; test all critical applications, run the network like you would with a full vessel underway, call the provider's Network Operations Center (NOC) on the weekend and ask questions. Increase the bandwidth temporarily to see the response time and establish what level best suits the ship. Also remember that networks can perform very differently in different geographic locations. Thus, it is recommended to ask for a Service-Level Agreement. Again, do not agree to a long-term time commitment.
9. Although SATCOM became attractive as the first satellite service billed at a fixed monthly fee, many providers are implementing Fair Access Policies (FAPs) where usage is throttled down at peak periods, or applying a monthly data cap with an

overage fee and an additional price per MB once your cap has been reached. That is okay if the cap is reasonable for your usage requirements, but many times it is much less than desired and/or your expected usage. Check the service's terms and conditions to make sure this doesn't happen, as it could double or triple the price that is on the price sheet.

10. A data cap can mean that you're only allowed a limited data amount each month. If you go above this cap, you will be charged extra per Mega Bite (MB). Find out what this data cap is and how much a MB will cost once you're over your limit. You should then check what your average usage will be and establish a cost baseline from there.
11. Don't pay for an annual high bandwidth contract when the ship will only steam for two months during the year. It's better to take minimum crew-level service and increase it temporarily when the ship is at sea.
12. Voice over IP (VoIP) is commonly misunderstood simply because your SATCOM provider providing your VoIP may not tell you anything about the quality of the service. It is important to know how your VoIP is transported for quality and security reasons. Many VoIP providers cut costs by transporting your voice packets for free over the public Internet, where quality can be hampered due to increased latency or other fades and delays. A quality SATCOM provider will transport VoIP calls over a fully private network.
13. Check how many satellites are above you—coverage maps from different SATCOM providers may look familiar, but these can be misleading. It's important to know that there is a selection of satellites available to you (As per the provider) in case of mast blockage and possible satellite fault. So ask for a detailed coverage map and opt for an automatic beam-switching solution that will ensure a seamless connection to the

satellite.

14. Be sure to know what level of provider you are working with. There are many different levels of providers, from a Tier One provider to a Virtual Network Operator (VNO), to simple resellers. Each level has different capabilities when it comes to how much of the network they operate and/or manage, significantly affecting the overall performance, service, and resolution time if a system or network issue is detected. Keep this in mind if you want to temporarily increase your bandwidth or need to move to another satellite.
15. Know who is in charge of the service—In case of service interruption or a connectivity issue, a cheap and common trick is to blame the equipment and go to the antenna manufacturer or the routers on the ship and then an argument ensues, leaving the ship engineer in the middle. All agreements should clearly state equipment and service responsibilities.
16. Just as with one's own cellphone contract, the service providers will seek lengthy contracts, avoid this as much as possible. By locking a poor service, the provider can have comfort in an income stream, yet your hands will be tied when seeking to move to a newer more advanced service.

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